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# Canada/NB MDA project on mine-shaft rope testing; testing of 1 7/8 in., 34×7, NR, T.R. (our rope #9)

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# CANADA/NB MDA PROJECT ON MINE-SHAFT ROPE TESTING: TESTING OF $1\frac{7}{8}$ IN., 34 × 7, NR, T.R. (OUR ROPE #9)

by

L.B. Geller*, D. Poffenroth†, J.E. Udd**, and D. Hutchinson††

## ABSTRACT

In this report the authors analyse the test-results obtained both non-destructively, and destructively, on a $1\frac{7}{8}$ in., 34 × 7, non-rotating (NR) tail-rope (T.R.). The rope was examined both in situ and on the shop-floor within the context of CANMET's project to comparatively evaluate the performance of a range of EM wire-rope testers. This is the first time a project of this magnitude and diversity has been undertaken.

The rope in question was reported as extensively corroded, with interstrand wear throughout the test-length, and a 30.0% loss-of-breaking- strength (LBS). The very fact of its exceptionally poor condition made its examination of special interest.

In the field electro-magnetic (EM) testing was performed with a Rotesco AC instrument. Six months after the last field-test the rope was also examined reel-to-reel on the shop-floor, with a range of five instruments. Unfortunately, only some 400-450 ft of the original 3,000 ft in situ length were available for shop-floor testing.

While the rope was removed when it reached the legal limit of deterioration, we think that ropes should not be left in service long enough to reach the condition that this rope was in. This is especially so in view of the considerable margin of error we often observed in case of EM instrument-based LBS estimates. Interestingly, a whole year seemed to have elapsed between the penultimate and ultimate routine EM tests of this rope, while it was tested at six month intervals before that.

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Keywords: New Brunswick; Mineral Development Agreement; wire-ropes; Non-destructive-testing; Electro-magnetic instruments; spin-resistant ropes

# ESSAIS DE CABLAGES DE PUITS DE MINE, DANS LE CADRE DE L'ENTENTE CANADA/N.B. SUR LE DÉVELOPPEMENT MINÉRAL ESSAI D'UN CABLE DE RENVOI ANTIGIRATOIRE DE 1-7/8 PO, 34 X 7 (Nº 9)

par

L.B. Geller[1], D. Poffenroth[2], J.E. Udd[3], et D. Hutchinson[4]

## RÉSUMÉ

Dans le présent rapport, les auteurs analysent les résultats obtenus à la suite d'essais destructifs et non destructifs sur un câble de renvoi antigiratoire de 1-7/8 po, 34 X 7. Le câble a été examiné à la mine et dans l'atelier, dans le cadre du projet CANMET, dans le but d'évaluer de façon com-parative le rendement d'une gamme d'appareils électro-magnétiques de vérification des câbles. C'est la première fois qu'un projet d'une telle envergure et d'une telle diversité est entrepris.

On nous avait averti que le câble en question était excessivement corrodé, que tous les torons étaient usés sur toute la longueur de l'éprouvette, et que le câble avait perdu 30,0% de sa résistance à la rupture. L'examen d'un tel câble revêtait donc un intérêt tout particulier, en raison de l'état dans lequel il se trouvait.

Sur place, des essais ont été effectués avec un appareil électro-magnétique Rotesco AC. Six mois après la dernière série d'essais sur place, le câble fut expédié à l'atelier et examiné de bout en bout à l'aide de cinq instruments différents. Malheureusement, des 3000 pi de câble disponibles à l'origine lors des essais sur place, il ne restait plus que 400 à 500 pi pour nos essais en atelier.

Bien que le câble ait été retiré du service une fois sa limite légale de détérioration atteinte, nous estimons qu'il n'est pas sécuritaire de laisser un câble en service assez longtemps pour qu'il atteigne le degré de détérioration que nous avons pu constater, tout particilièrement à la lumière de l'importante marge d'erreur que nous avons pu observer dans les lectures d'instruments électro-magnétiques sur lesquelles sont basées les estimations de résistance à la rupture. Chose intéressante, il semble s'être écoulé un an entre le dernier et l'avant-dernier contrôle électro-magnétique de routine de ce câble tandis qu'il était contrôlé à tous les six mois auparavant.

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Mots clés: Nouveau-Brunswick, Entente sur le développement minéral, câble métallique, essais non destructifs, instruments électro-magnétiques, câble anti-giratoire.

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## BACKGROUND

The results described in this report constitute an integral part of the contracted phase of CANMET's project, undertaken in 1986 in response to requests by both the mining industry and its regulators. The basic project objectives specified that the continuing rope failures, or near failures — occurring despite mandatory wire-rope examinations with electro-magnetic (EM) instruments at regular intervals — be examined, analysed, and clarified. This is the first time a project of this scope and depth has been undertaken, anywhere.

CANMET's work included both in-house and contracted work phases. The in-house phase resulted in a range of conclusions and recommendations, reported elsewhere (1, 2, 3, 4). We are now in the process of reporting the results obtained during the contracted project-phase, which included an extensive series of in situ and shop-floor tests. The first four reports of this series were published in February, May, and June, 1990 (5, 6, 7, 8). This is the fifth such report. More are to follow.

## ROPE DETAILS

The rope of current interest (referred to as "our rope #9") was designated #7 Tail-Rope in Shaft #2 of Denison-Potacan Potash Company's Clover Hill mine at Sussex, New Brunswick. It was manufactured by Greening Donald Ltd. at Hamilton, Ontario. Its reel number was G1074. It measured 54 mm ($2\frac{1}{8}$ in.) diam × 890 m (2,920 ft)*.

It was of a $34 \times 7$ non-rotating (NR) construction ($34 \times 2.79$; $204 \times 2.64\ mm$), with a mass of 11.8 kg/m (7.91 lb/ft); right-Langs-lay; galvanized plow steel. Its breaking strength was 186,363 kg (410,000 lb), as per Ontario MOL test certificate #64991. It was purchased on 24.8.84; installed on 7.6.85, and removed on 15.12.88 (42 months in use). As is well known, and has been pointed out in our previous reports (3, 6, 8), non-destructive testing (NDT) with EM instruments must not be done in isolation. It is very important to be aware of the previous NDT test-results obtained on the tested rope as well as on its companion-ropes and predecessors. This is particularly important in a case like the present one, with the rope of interest in an exceptionally poor condition.

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*: only a 400-450 ft section of this original length was available for shop-floor testing. Moreover, its diameter was found to be $1\frac{7}{8}$ in. We could not obtain an explanation for the difference between the rope size on the shop-floor and the one of record at the mine

We note that of the three $2\frac{1}{8}$ in. 34 × 7 tail-ropes installed in shaft #2 in June 1985, only #8 was replaced — in May 1988, after 35 months service — before the October 1988 Rotesco AC in situ tests we are now considering. We provide details of the relevant Rotesco field tests hereunder.

## IN SITU TEST RESULTS — AS REPORTED AND REVIEWED

In situ test results were obtained with a Rotesco AC instrument at regular intervals. The 1985-1988 rope, of current interest, was tested along a length of some 2,730 ft. These tests were undertaken on 23.9.85 (test #GMP-9); on 26.2.86 (test #MDMP-23); on 9.9.86 (test #DI-MP-24); on 8.3.87 (test # DMP-30); on 29.9.87 (test #DMP-80); and on 3.10.88 (test #CBMP-24). The maximum reported LBS values were 0.0%; 2.0% (Fig. 1a); 2.0%; 3.0% (Fig. 1b); 7.0% (Fig. 1c); and 30.0% (Fig. 1d). Maximum losses were reported some 200-340 ft, and 430-645 ft below the North skip, as well as some 55-65 ft below the South skip. Rotesco only reported LBS values. We converted these into the corresponding loss-of-metallic-area (LMA) chart data by dividing the reported LBS values with the appropriate "factor", obtained from the Rotesco AC's operating manual. It lists factors of 1.77, 1.80, and 1.66 for $2\frac{1}{16}$ in., $2\frac{1}{4}$ in., and $1\frac{3}{4}$ in. diameter ropes, respectively. A major Canadian mining company uses a factor of 1.7 for a $1\frac{7}{8}$ in. rope.

We reported previously (3) that we found no record of any routine EM test having been performed on this rope when expected, namely, during the Spring of 1988. We also commented earlier (3) on the inadvisability of leaving a rope in service until its reported $LBS_{max}$ actually reaches the, then, legal limit of 30.0%. This is particularly inadvisable in view of the uncertain accuracy with which the $LBS_{max}$ is estimated on the basis of the EM chart readings. We documented this uncertainty in several earlier reports (1, 2, 3, 7).

We cut and realigned (Figures 1e and 1f) the Rotesco AC test-charts of 29.9.87 and 3.10.88 to provide a clearer overview of the rope conditions at these test-stages. From Figure 1f it would appear, that in October 1988, the rope condition was even worse than reported, insofar as the $LMA_{max}$ was some 24.0–26.0%, rather than the 18.0% one obtains on the basis of Rotesco's 30.0% $LBS_{max}$ report, and their referenced conversion "factor". We, therefore, have doubts about the accuracy of the operator's report.

Interestingly, the condition of the other $2\frac{1}{8}$ in. 34 × 7 tail rope (#9), which was also in use since June, 1985, was just as bad (Fig. 2b). The third tail-rope (#8) was, of course, in much better shape (Fig. 2a), having been installed more recently (i.e., on 17.5.88). The relevant Rotesco AC tests were undertaken on 3.10.88. For rope #9 the test was #CBMP-26, and the $LBS_{max}$ 30.0%, some 200-240 ft below the South skip. For rope #8 the test was #CBMP-25, and the $LBS_{max}$ only 1.0%. The relevant Rotesco charts, as marked by ourselves, are reproduced in Figures 2c and 2d.

## SHOP FLOOR TEST RESULTS — AS REPORTED AND REVIEWED

### General procedure

The shop-floor tests were undertaken with a Rotesco AC, a Magnograph, a Rotescograph, an LMA-250, and with the prototype version of the latest German WBK instrument. None of the operators knew about each other's results before these were submitted to us. All details of the testing process have been described, and illustrated, elsewhere (5).

At this time we have not, as yet, received the German test results. We shall publish these later, as soon as they become available.

### The Rotesco AC data

The Rotesco AC data were obtained on 17.3.89 (Fig. 3a), and again on 3.4.89 (Fig. 3b). In each case the instrument was used on its own. The permanent-magnet instruments were then used together, later than the Rotesco AC. This was done to ensure proper rope demagnetization. Since shop-floor testing with the Rotesco AC was done twice, the operator should have been able to adjust his LMA sensitivity setting on the second occasion to ensure that the trace remained on the chart. Rope movement through the instrument was in opposite directions on the two test occasions.

The operator reestablished the zero on his LMA chart during the 17.3.89 test once (Fig. 3a). He did so several times during his 3.4.89 test run (Fig. 3b). We, therefore, cut and realigned his charts (Figures 3c and 3d), to provide a clearer overview of the test results. On the basis of his 3.4.89 test the operator reported an $LMA_{max}$ of 17.0% — with a corresponding $LBS_{max}$ of 30.0% — some 220 ft from test start. He had set his 0% LMA reference level about 30 ft from test start. From Fig. 3d we actually read an $LMA_{max}$ of 12.0%, some 220 ft from test start. The corresponding $LBS_{max}$ is only 20.4%. We do not, therefore, agree with the operator's report submitted to us.

As pointed out before, rope #9 was only a short section of the original T.R. #7, and did not contain the "best" and "worst" sections of the entire in situ rope. The $LMA_{max}$ read on the shop-floor test-chart cannot, therefore, be compared with the one read off the Rotesco AC in situ test chart.

We have commented in earlier reports (5, 6, 8) on the remarkable degree of repeatability and comparability between instrument charts — especially in case of dual-function testers — even when obtained by different operators, at different locations (including in situ vs reel-to-reel situations), and at different times. We should, therefore, be able to determine which section of the original tail-rope #7 the mine sent to us, by juxtaposing the in situ and reel-to-reel test charts. This was done in Fig. 4. Unfortunately, on this occasion, we do not have any dual-function instrument charts from both locations, only the Rotesco AC traces. This makes comparisons more difficult, especially since we cannot expand the relatively short 400 ft reel-to-reel chart. Even so, it looks as if our rope #9 is the 150-500 ft section of the original rope. Consequently, it contains neither the "best", nor the "worst" sections of the original tail-rope #7. This would not matter, were we to obtain absolute LMA test results. However, our chart-readings are only relative ones, i.e., LMA's relative to the best section of whatever rope length is actually available.

Nonetheless, our shop-floor tests are of considerable interest, because they provide comparative results with a range of instruments on the same, badly corroded and worn, rope-length.

## The LMA-250 data

Testing was done on 17.3.89 (Fig. 5a), and on 4.4.89 (Fig. 5b) on a rope length of some 400 ft. The rope moved in opposite directions on these two test occasions. Because of the rope's exceptionally poor condition, the seizing wire markers, on a 250 ft spacing, did not show up well. Their location is, however, identified by the symbols 'M1' and 'M2' on Fig. 5b. Repeatabilility of the EM measurements is remarkably good. This is clearly documented by Figures 5a and 5b. Whenever we were unable to reproduce the entire instrument chart in a single stretch, we provided match-marks (such as ref. 'A'; ref. 'B'; etc.) on the individual chart-segments.

Regarding the rope's overall condition we quote, with approval, from the operator's report: "A rope in this adverse condition is dangerous to test non-destructively, because the severe kink catches on the test-head. A visual inspection would indicate that the rope should be retired. It is not known how much loss of metallic area there was at the kink, because the pen went off scale (refer to strip-chart, LMA channel), but the largest measurable loss was 23.5% near marker 'M2'. The losses were probably much greater than that measured, because the section showing the greatest metallic area was in a severely corroded or notched section. This rope should have been retired before it reached this condition."

We might add to the operator's comments that which we pointed out before in connection with Fig. 4, namely that our rope #9 does not contain the "best" rope section of the original tail-rope #7. Lacking this rope-section the "true" 100% reference level cannot be correctly placed. Consequently, the shop-floor and in situ test-results cannot be compared as to maximum LMA's, unless we place the 100% reference level in accordance with its in situ chart position. Only the shop-floor LMA's can be reliably compared, among each other. Doing this we note that the two LMA-250 chart-readings (Figures 5a and 5b) are very similar.

We accepted both of the operator-reports as being correct.

## The Magnograph data

Testing was done on 4.4.89. The operator's report (#89-286B) was limited to an evaluation of his chart between 112 and 397 ft (Fig. 6a). In this section he reported an $LMA_{max}$ of 20.0%. The seizing wire markers, on a 250 ft spacing, did not show up well, due to the very bad rope-conditions. However, the operator marked the position of the one present in Fig. 6a. It is identified by the symbol 'Mk 250 pi'. Interestingly, its location does not exactly match that of the 'M2' symbol on Fig. 5b.

The LBS was reported to be 40.5% at 301 ft from test start, and 55.0% at 366 ft. Since the operator's report, and chart, did not cover the whole of our rope #9, we could not accept it. First we had to see the entire chart, to decide whether any mistakes might have been made, e.g., in placing the 100% reference level. In response to our request, the operator sent us the chart reproduced in Fig. 6b. On the margin he commented that "the LMA trace was not reliable". We found this chart to be of little help. Nor could we accept the operator's comment as being correct. We, therefore, asked for a copy of his magnetic test-tape. In possession of the tape, we produced our own chart print-out (Fig. 6c). Its LMA-gain setting of 1.9% per major chart-division is, however, an awkward one. To facilitate comparisons with the operator's original submission to us (Fig. 6a), we produced another Magnograph chart (Fig. 6d) with the more common 2.5% per major chart division.

On comparing Figures 6c and 6d with Fig. 6a it can be seen that, in fact, the operator positioned his 100% reference line correctly*. Consequently, his $LMA_{max}$ chart-reading of 20.0% at 366 ft from test-start is correct. However, it also appears that the operator was unclear as to the actual significance of the events on his chart. In any case, one should not accept a report based on a partial test-chart. In summary: we could not accept the operator's report unhesitatingly, but found it to be correct, if incomplete, on checking.

On juxtaposing, in Fig. 6e, our Magnograph chart-copy (Fig. 6c) and the LMA-250 operator's chart (Fig. 5b), both obtained on the shop-floor on 4.4.89, but with different instruments and different operators, the striking similarity of the two traces becomes self-evident. The LMA-250 chart-readings are, however, everywhere greater than the corresponding Magnograph ones. The difference is mostly, but not everywhere, within the "acceptable" ±2.0% benchmark range we had set in an earlier report (5).

## The Rotescograph data

Testing was done on 17.3.89 (Fig. 7a), on 5.4.89 (Fig. 7b), and on 10.4.89 (Fig. 7c), on test lengths reported to be 337 ft, 397 ft, and 369 ft, respectively. In fact, the test lengths were identical on all three occasions. Chart speeds were reported at 5 mm/sec on all three occasions. Considering, however, the different strip-chart lengths, spacing of the 10 ft distance markers at the chart-edge, and the known test-rope speeds (in the order of 40-80 ft/min), we think that a 5 mm/sec chart-speed was used only on 17.3.89 and 10.4.89. On 5.4.89 the likely chart-speed was 1 mm/sec.

Whenever we were unable to reproduce the entire instrument chart in a single stretch, we provided match-marks (such as ref. 'A'; ref. 'B'; etc.) on the individual chart-segments. The seizing wire markers, on a 250 ft spacing, did not show up well, due to the very bad rope-conditions. However, the operator identified their location by writing 'Marker' on Figures 7b and 7c.

The rope moved through the Rotescograph's test-head in the same direction during the 17.3.89 and 10.4.89 tests, but in the opposite direction on 5.4.89. Actually the latter date is incorrect. The test was undertaken on 4.4.89, in conjunction with the Magnograph and LMA-250 instruments.

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*: to facilitate chart comparisons, we mounted Figures 6a and 6d on the same report page, as well as Figures 6b and 6c

The operator did not submit a report on his latter test-run. We ourselves marked up Fig. 7b with the 0% LMA reference level, and with the LMA chart readings at the appropriate locations. We chose these locations — marked as defects '#1', '#2', etc. to '#9' and 'kink' — in correspondence with the ones on the LMA-250 and Magnograph charts (Fig. 6e). Since all three of these tests were performed at the same time, the rope moved in the same direction on all three charts.

As has been reported before (5, 6, 8), the comparability of these test-charts, obtained on the same rope at the same time, but with different instruments and different operators, is quite remarkable. All characteristic rope-features, i.e., "fingerprints", of the dual-function LMA chart-traces are quite unmistakable. These features, including the huge rope-kink, are more difficult to identify on the single-function Rotesco AC instrument charts (Figures 3a and 3b).

While the comparability of the chart-trace shapes is excellent, this is, unfortunately, not the case with the quantitative results (Table 1). In fact their scatter is "unacceptable", insofar as it exceeds the ±2.0% benchmnark level we have set in a previous report (5). This is so not only in case of different instruments (Rotescograph vs LMA-250), but also for the different Rotescograph LMA chart-readings of 17.3.89 and 10.4.89. The LMA-250 instrument's LMA chart-readings are consistently the highest; the Magnograph's the next highest; and the Rotescograph's the lowest.

Setting of the location of the "best" rope segment is not as uniform among the three test-runs as would have been expected. In this context it is of interest to note that there is a "best" rope section, of almost equal quality, on both sides of the rope-kink.

While there was no operator report for the 5.4.89 test-run, there were reports and marked charts for the 17.3.89 (Fig. 7a), and 10.4.89 (Fig. 7c) tests. For the earlier test the operator set the 0%LMA reference level at 253 ft from test-start (i.e., just past the rope-kink). For the latter test he set this level at 153 ft from test-start. For his LBS estimates the operator simply doubled the corresponding LMA chart-readings. On reviewing the respective charts and reports, our comments are as follows:

The 17.3.89 test-run (Fig. 7a):

The location of the 0%LMA reference level is incorrectly chosen just past the rope-kink. It should have been placed some 305-312 ft from the test-start, even though, quantitatively, this happens to make little difference in the present case. The quantitative LMA results are examined in Table 1. In line with the operator's practice, we doubled the corresponding LMA chart-readings to obtain the LBS estimates;

The 10.4.89 test-run (Fig. 7c):

Since the operator reestablished his zero on this LMA chart immediately ahead of the rope-kink, we cut and realigned (Fig. 7d) the operator's original chart (Fig. 7c) in order to provide a clearer overview of the test-results. The operator chose his 0%LMA reference level at 135 ft from test start. We agree with his choice. We would, however, point out that, in this case, the operator's chart fails to locate the second, almost equally sound, rope segment in the 250-369 ft rope section. We noted its presence there in the Magnograph, the LMA-250 (Fig. 6e) and in the 5.4.89 Rotescograph (Fig. 7b) charts. Presumably this inaccuracy is of human origin, caused by the LMA zero readjustment.

The quantitative LMA results are examined in Table 1. In most cases our review confirms the operator's reported results, even though, as pointed out above, we disagree with certain report aspects. In line with the operator's practice, we doubled the corresponding LMA chart-readings to obtain the LBS estimates.

## DESTRUCTIVE TESTING

Four 16-ft samples were cut from our rope #9 for destructive and visual testing. Of these, contiguous samples, each 8 ft long, were used for destructive testing as well as for external and internal visual inspection. Results of the latter work are not yet available.

The general test procedure was described, and illustrated, elsewhere (6).

The samples were designated as sample #9a, #9b, #9c, and #9d. With reference to Fig. 6c:

Sample #9a: cut from test-start rope-end, i.e., from rope section containing an LMA chart-reading of 8.6%;

Sample #9b: cut from defect #8 rope-segment, i.e., from rope section containing an LMA chart-reading of 17.5%;

Sample #9c: cut from defect #6 rope-segment, i.e., from rope section containing an LMA chart-reading of 19.5%;

Sample #9d: cut from defect #1 rope-end, i.e., from rope section containing an LMA chart-reading of 7.8%.

Destructive testing was performed in the laboratories of Wire Rope Industries (WRI) Ltd., at Pointe Claire, Quebec. It was monitored by Messrs. G. Rousseau (from CANMET) and R. Bole (from WRI). Standard procedures were followed.

As mentioned before, the original breaking strength of the #7 T.R. was determined by the Rope Testing Laboratory of the Ontario Ministry of Labour, in Toronto. According to their test certificate #64991 of 4.2.85 it was found to be 410,000 lb. This can, indeed, be the strength of a 54 mm ($2\frac{1}{8}$ in.), 34 × 7, rope. However, as mentioned before in this report, our rope #9 was, in fact, a $1\frac{7}{8}$ in., 34 × 7, tail-rope. The catalogue strength of such a rope is only in the order of 262,000 lb. We were unable to determine where else this rope could have come from, other than indicated to us in the first place. Moreover, the comparison of the in situ and shop-floor Rotesco AC charts (Fig. 4) seems to confirm its origin. Although unable to clarify this point, concerning the puzzling difference in rope diameters, we provide the destructive test results hereunder:

Sample #9a: 128,500 lb, i.e., a loss of 50.9% of the original 262,000 lb strength, at a point where the maximum LMA chart reading is 8.6% (Fig. 6c). The sample diameter was 1.880 in.;

Sample #9b: 111,000 lb, i.e., a loss of 57.6% of the original 262,000 lb strength, at a point where the maximum LMA chart reading is 17.5% (Fig. 6c). The sample diameter was 1.910 in.;

Sample #9c: 130,500 lb, i.e., a loss of 50.2% of the original 262,000 lb strength, at a point where the maximum LMA chart reading is 19.5% (Fig. 6c). The sample diameter was 1.870 in.;

Sample #9d: 191,000 lb, i.e., a loss of 27.1% of the original 262,000 lb strength, at a point where the LMA chart reading is 7.8% (Fig. 6c). The sample diameter was 1.830-1.870 in.

The conditions of the broken samples were as follows:

In general: all samples showed heavy rust and rust-pitting of the wires, and very heavy inter-layer nicking. The wires broke in shear at the nicks. Moreover, samples 9b and 9c showed many existing internal fatigue breaks;

Sample #9a: six strands broke on outer layer, near sample centre;

Sample #9b: 11 outer, and five middle strands broke, near sample centre;

Sample #9c: ten outer, and three middle strands broke, about 2-ft from cone;

Sample #9d: some 60% of the strands broke, in all layers, at sample centre.

Although we are unable to say, with any degree of certainty, how much the original breaking strength of this rope was, it seems unlikely to have been 410.000 lb. Consequently, we based the foregoing "true" LBS values on the more likely 262.000 lb catalogue value. On this basis, the Magnograph operator's LBS estimates of 40.5% for the defect #6 rope segment (Fig. 6a), and 55.0% for the defect #2 rope segment (Fig. 6a), appear quite reasonable. The Rotescograph operator's corresponding LBS estimates are 33.0% and 36.0%, obtained by doubling the 17.3.89 test's reported %LMA chart-readings at the given rope locations (Fig. 7a). These LBS estimates are on the low side; but so are the Rotescograph operator's LMA chart-readings on the whole, as has been noted both in this, and in previous reports (5, 6, 8).

## SUMMARY

Our comparisons in Table 1 are based on a number of characteristic rope-defects — identified as '#1' to '#9' and 'kink' — which are readily recognizable on the dual-function instruments' strip-charts (Figures 6e and 7). This is not so in case of the Rotesco AC's LMA chart. Here, we could only distinguish the rope-kink, and defects #1 and #2; the former because it causes the maximum LMA chart-reading; and the latter because they are known to be close to the rope-end of the segment that measures about 280 ft from the rope-kink to rope-end.

Although, in most cases, our review confirms the validity of the operator's chart-readings, in a number of cases we disagree with the operator's choice of the 100% reference-level location.

Only one test was performed with the Magnograph. In case of the 17.3.89 and 4.4.89 tests with the LMA-250, the "repeatability" of the LMA chart-readings is excellent. This is not the case with the three Rotescograph tests, possibly due to a human error in instrument calibration. In fact, in a number of cases the difference between the corresponding LMA chart-readings is "unacceptable" — i.e., it is in excess of the ±2.0% benchmark level we set elsewhere (5). This is so not only in case of different instruments (Rotescograph vs LMA-250), but also in case of the 17.3.89 and 10.4.89 Rotescograph results themselves.

In the present case, and among the dual-function instruments, the LMA-250 instrument's chart-readings are consistently the highest; those of the Magnograph the next highest; and those of the Rotescograph the lowest. The Rotesco AC's chart-readings are the lowest altogether, presumably due to its relatively weak magnetic field.

At this time we are unable to say which of the the foregoing results are closest to the "true" metallic-area rope losses, because the latter have not, as yet, been determined.

On the basis of a new $1\frac{7}{8}$ in., 34 × 7, rope's catalogue breaking-strength, the Magnograph operator's LBS estimates are of the correct order of magnitude.

Only shop-floor test results are listed in Table 1. No reliable comparison can be made between these, and the in situ results, because: (a) only a 400-450 ft length of the approximately 2,730 ft in situ tail-rope #7 was available to us for reel-to-reel testing, (b) it did not contain either the "best", or the "worst" segments of the in situ rope, and (c) we cannot be certain that the $1\frac{7}{8}$ in. rope-segment on the shop-floor was, in fact, cut from the #7 tail-rope, even though our documents indicate that this was the case. Therefore, we record brief details of both the in situ and shop-floor test set-ups, and of their results (Tables 2 and 3), but can not draw any definite conclusions from their comparison.

Our rope #9 contained an unusual number of major rope-defects, whose characteristic shapes can be pin-pointed on the LMA chart-traces of the various instruments. The test-series of current interest, therefore, provides a good opportunity for checking out the accuracy of the length indications along the edge of the different strip-charts. This has been done, and the results tabulated (Table 4). This table also reflects the fact that on 17.3.89 rope lengths were measured from the same rope end by the LMA-250 and the Rotescograph, and again on 10.4.89 by the Rotescograph. On 4.4.89 though (actually the Rotescograph operator's 5.4.89 chart-date should also read 4.4.89) length measurements were taken the other way around. This causes a little difficulty in directly comparing the footage values of Table 4. We, therefore, also tabulated the distances between the various rope-defects.

The latter distances are in remarkably good agreement, even though obtained by different operators, on different occasions, and with different instruments. Even the corresponding footage chart-readings are seen to be in reasonable agreement, if due allowance is made for the obvious uncertainty in accurately locating the point of test-initiation (note the widely differing overall test-lengths reported for the exact same rope length). A clear test-start indication, say by taping to the test-rope a small magnet, or a sufficiently long calibration wire, would be very helpul in this context. We have referred to this problem elsewhere (5, 6, 8).

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2. Geller, L.B.; Anderson, G.L.; Miscoe, A.J.; and Mitchell, E.W. "The safety of mine-shaft wire-ropes — cooperative work by Canada and the U.S.A.": CANMET Division Report MRL 89-14, 28 pp; February, 1989.
3. Geller, L.B.; Udd, J.E.; Blanchard, R.; and Daniel, K.E. "About electro-magnetic wire-rope testing in New Brunswick mines, and related data"; CANMET Division Report MRL 89-40, 51 pp; October, 1989.
4. Geller, L.B.; and Rousseau, G. "Effect of trapped wire-rope debris upon an EM instrument's LMA chart-trace"; CANMET Division Report MRL 90-08, 29 pp; February, 1990.
5. Geller, L.B.; Rousseau, G.; and Poffenroth, D. "Canada/NB MDA project on mine-shaft rope testing; stranded ropes with artificial defects"; CANMET Division Report MRL 90-15, 117 pp; February, 1990.
6. Geller, L.B.; Poffenroth, D.; Udd, J.E.; and Hutchinson, D. "Canada/NB MDA project on mine-shaft rope testing; testing of 1 1/4 in., FLC, H.R. (our rope #4)"; CANMET Division Report MRL 90-044, 76 pp; May, 1990.
7. Geller, L.B.; Poffenroth, D.; Udd, J.E.; and Hutchinson, D. "Evaluation of EM rope testers: Canada/US cooperative work"; CANMET Division Report MRL 90-052, 24 pp; June, 1990.
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# APPENDIX

## Tables 1, 2, 3, and 4,

## as well as Figures 1 to 7, inclusive

## Table 1

### LMA chart-readings; shop-floor tests

| Rope defect | Rotesco | LMA-250 | | Magnograph | | Rotescograph | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | AC | 17.3.89 | 4.4.89 | 4.4.89 | 4.4.89 | 17.3.89; Fig. 7a | | 5.4.89** | 10.4.89*** | |
| | 3.4.89* | Fig. 5a | Fig. 5b | Fig. 6a | Fig. 6c | $\alpha$ | $\beta$ | $\beta$ | $\alpha$ | $\beta$ |
| #1 | 10.7% | 21.2% | 21.8% | 18.6% | 19.5% | 16.5% | 16.8% | 11.7% | 10.0% | 11.2% |
| #2 | 10.7% | 23.3% | 23.5% | 19.7% | 20.7% | 17.0% | 18.0% | 13.3% | 11.5% | 11.5% |
| #3 | | 21.0% | 21.0% | 17.4% | 18.0% | 15.5% | 15.6% | 12.1% | 10.0% | 10.8% |
| #4 | | 20.0% | 19.5% | 15.8% | 16.4% | 14.5% | 14.8% | 11.3% | 10.0% | 10.4% |
| #5 | | 17.8% | 18.0% | 14.6% | 14.8% | 13.0% | 13.7% | 10.2% | 8.5% | 9.2% |
| #6 | | 23.3% | 23.5% | 20.0% | 19.5% | 16.5% | 16.4% | 12.9% | 11.5% | 11.5% |
| #7 | | 18.7% | 19.0% | 13.0% | 13.3% | 13.5% | 14.1% | 11.0% | 9.0% | 10.0% |
| #8 | | 18.8% | 20.2% | 16.5% | 17.5% | — | 14.6% | 10.2% | 10.5% | 11.5% |
| kink | 12.0% | 34.0% | 39.0% | — | 21.9% | 20.0% | 20.5% | 17.2% | 22.5% | 23.0% |
| #9 | | 17.6% | 18.0% | — | 13.5% | 10.5% | 10.9% | 9.4% | 10.0% | 13.3% |

$\alpha$ = as reported; $\beta$ = as reviewed

*: Fig. 3d

**: Fig. 7b

***: Fig. 7c for $\alpha$, and Fig. 7d for $\beta$

**Table 2**

**Details of EM testing of the 1 7/8 in., 34 × 7, NR, T.R.**

| Item No. | Test Instr. | Test No. | Test date | Test location | Instr. operator* |
|---|---|---|---|---|---|
| 1 | Rotesco AC | MDMP-23 | 26.2.86 | in situ | (1) |
| 2 | Rotesco AC | DMP-30 | 8.3.87 | in situ | (1) |
| 3 | Rotesco AC | DMP-80 | 29.9.87 | in situ | (1) |
| 4 | Rotesco AC | CBMP-24 | 3.10.88 | in situ | (1) |
| 5 | Rotesco AC | — | 17.3.89 | shop-floor | (4) |
| 6 | Rotesco AC | — | 3.4.89 | shop-floor | (4) |
| 7 | LMA-250 | — | 17.3.89 | shop-floor | (5) |
| 8 | LMA-250 | — | 4.4.89 | shop-floor | (5) |
| 9 | Magnograph | 89-286B | 4.4.89 | shop-floor | (2) |
| 10 | Rotescograph | — | 17.3.89 | shop-floor | (6) |
| 11 | Rotescograph | — | 5.4.89 | shop-floor | (6) |
| 12 | Rotescograph | — | 10.4.89 | shop-floor | (6) |

*: (1) instr. maker and service company

(2) service company

(4) and (6) mining company

(5) government organization

## Table 3

$LMA_{max}$ chart readings and $LBS_{max}$ estimates
Items 1–4: in situ tests; Items 5–12: shop-floor tests

| Item No. | Test Instr. | As reported | | As reviewed | | As per Fig. No. |
|---|---|---|---|---|---|---|
| | | $LMA_{max}$ | $LBS_{max}$ | $LMA_{max}$ | $LBS_{max}$ | |
| 1 | Rotesco AC | 1.2% | 2.0% | 1.2% | 2.0% | 1a |
| 2 | Rotesco AC | 1.8% | 3.0% | 1.8% | 3.0% | 1b |
| 3 | Rotesco AC | 4.1% | 7.0% | 3.5% | 6.0% | 1c & 1e |
| 4 | Rotesco AC | 17.6% | 30.0% | 26.0% | 44.2% | 1d & 1f |
| 5 | Rotesco AC | — | — | 10.9% | 18.5% | 3a & 3c |
| 6 | Rotesco AC | 17.0% | 30.0% | 12.0% | 20.4% | 3b & 3d |
| 7 | LMA-250 | 34.0% | — | 34.0% | — | 5a |
| 8 | LMA-250 | — | — | 39.0% | — | 5b |
| 9 | Magnograph | 20.0% | 55.0% | 19.5% | — | 6a, 6c, 6d |
| 10 | Rotescograph | 20.0% | 40.0% | 20.5% | 41.0% | 7a |
| 11 | Rotescograph | — | — | 17.2% | 34.4% | 7b |
| 12 | Rotescograph | 22.5% | 45.0% | 23.0% | 46.0% | 7c & 7d |

## Table 4

### Location of rope-defects; accuracy of chart length-indications

| | Distance from test-start – ft, and, in brackets, — (distance between defects – ft) | | | | | | |
|---|---|---|---|---|---|---|---|
| | LMA-250 | | Magnograph; 4.4.89 | | Rotescograph | | |
| Rope defect | 17.3.89<br>Fig. 5a | 4.4.89<br>Fig. 5b | reported<br>Fig. 6a | reviewed<br>Fig. 6c | 17.3.89<br>Fig. 7a | 5.4.89<br>Fig. 7b | 10.4.89<br>Fig. 7c |
| #1 | 15<br>— (15) | 385<br>— (14) | 382<br>— (16) | 402<br>— (13) | 19<br>— (13) | 377<br>— (15) | 18<br>— (14) |
| #2 | 30<br>— (12) | 371<br>— (13) | 366<br>— (13) | 389<br>— (12) | 32<br>— (9) | 362<br>— (12) | 32<br>— (10) |
| #3 | 42<br>— (17) | 358<br>— (18) | 353<br>— (14) | 377<br>— (18) | 41<br>— (17) | 350<br>— (16) | 42<br>— (15) |
| #4 | 59<br>— (27) | 340<br>— (25) | 339<br>— (28) | 359<br>— (28) | 58<br>— (24) | 334<br>— (26) | 57<br>— (23) |
| #5 | 86<br>— (9) | 315<br>— (10) | 311<br>— (10) | 331<br>— (10) | 82<br>— (8) | 308<br>— (10) | 80<br>— (8) |
| #6 | 95<br>— (21) | 305<br>— (20) | 301<br>— (21) | 321<br>— (24) | 90<br>— (19) | 298<br>— (18) | 88<br>— (18) |
| #7 | 116<br>—(129) | 285<br>—(117) | 280<br>— (109) | 297<br>— (126) | 109<br>— | 280<br>— (129) | 106<br>— (112) |
| #8 | 245<br>— (40) | 168<br>— (50) | 152<br>— (40) | 171<br>— (42) | —<br>— | 151<br>— (33) | 218<br>— (37) |
| kink | 285<br>— (23) | 118<br>— (27) | 112<br>— | 129<br>— (33) | 255<br>(23) | 118<br>— (23) | 255<br>— (20) |
| #9 | 308 | 91 | — | 96 | 278 | 95 | 275 |
| Tested, per chart | 394 ft | 408 ft | 112 to 397 ft | 417 ft | 337 ft | 397 ft | 369 ft |

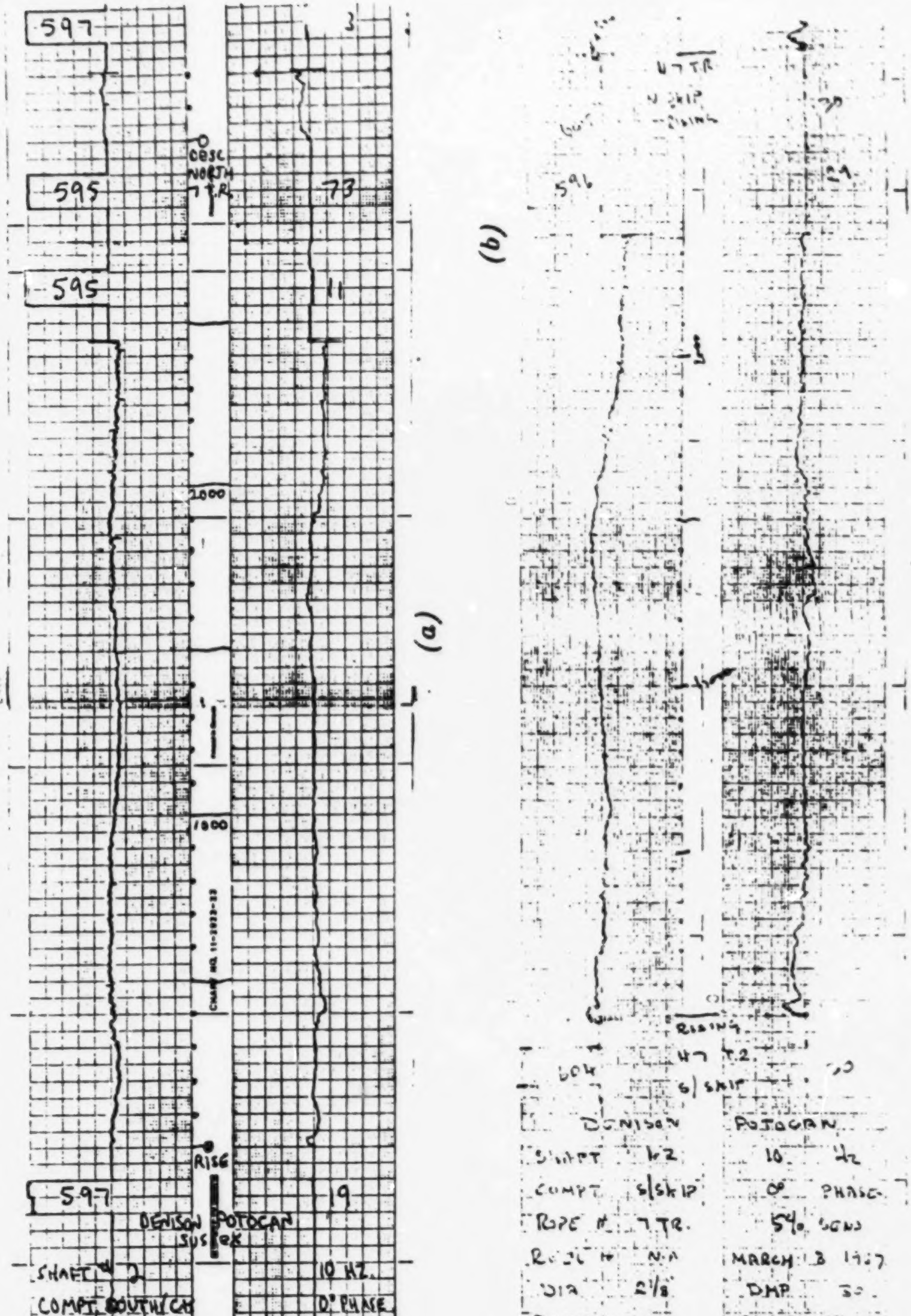


Fig. 1 — Rotesco AC in situ tests of tail-rope #7 of: (a) 26.2.80, and (b) 8.3.87

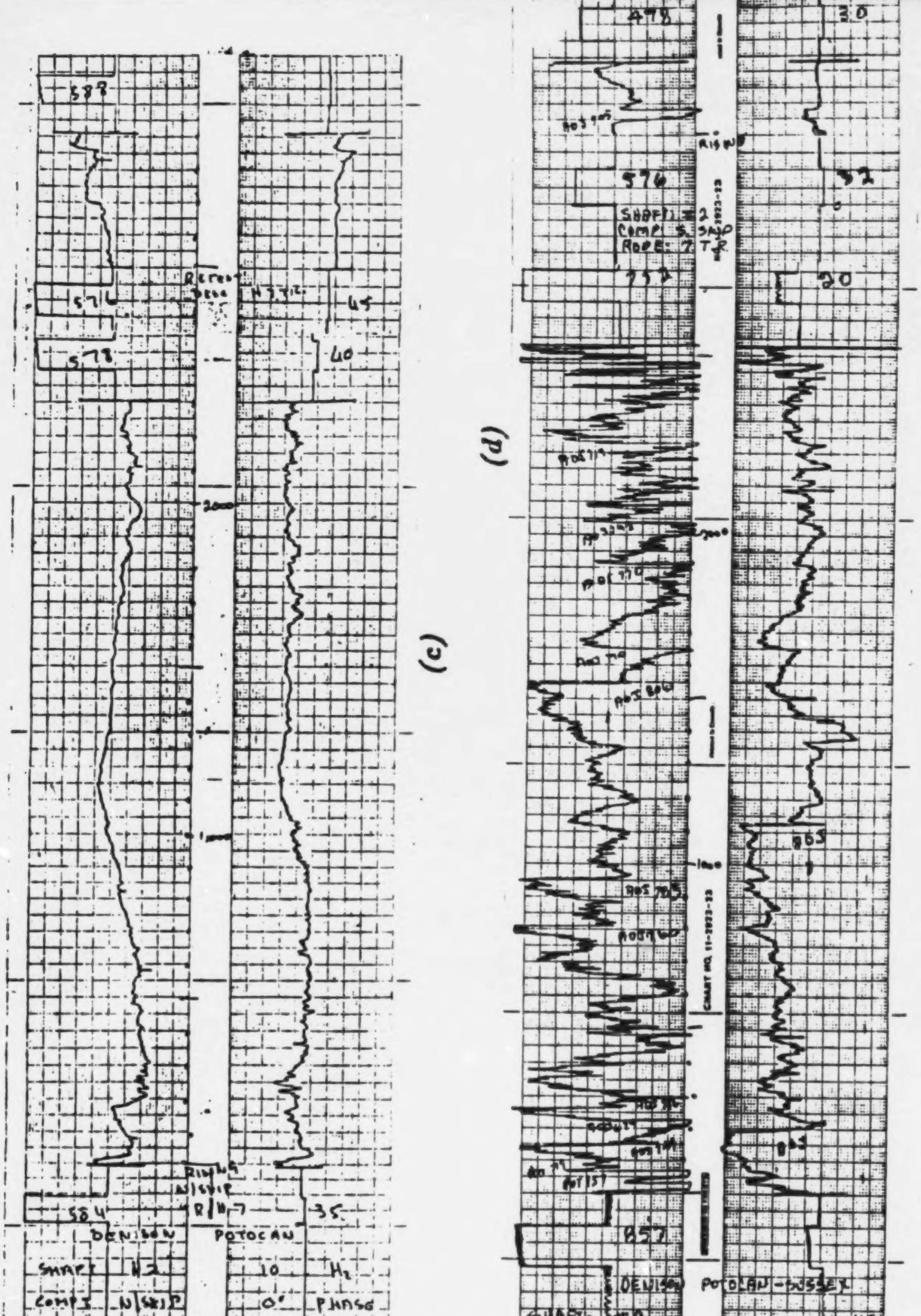


Fig. 1 (continued) — Rotesco AC in situ tests of tail-rope #7 of: (c) 29.9.87, and (d) 3.10.88

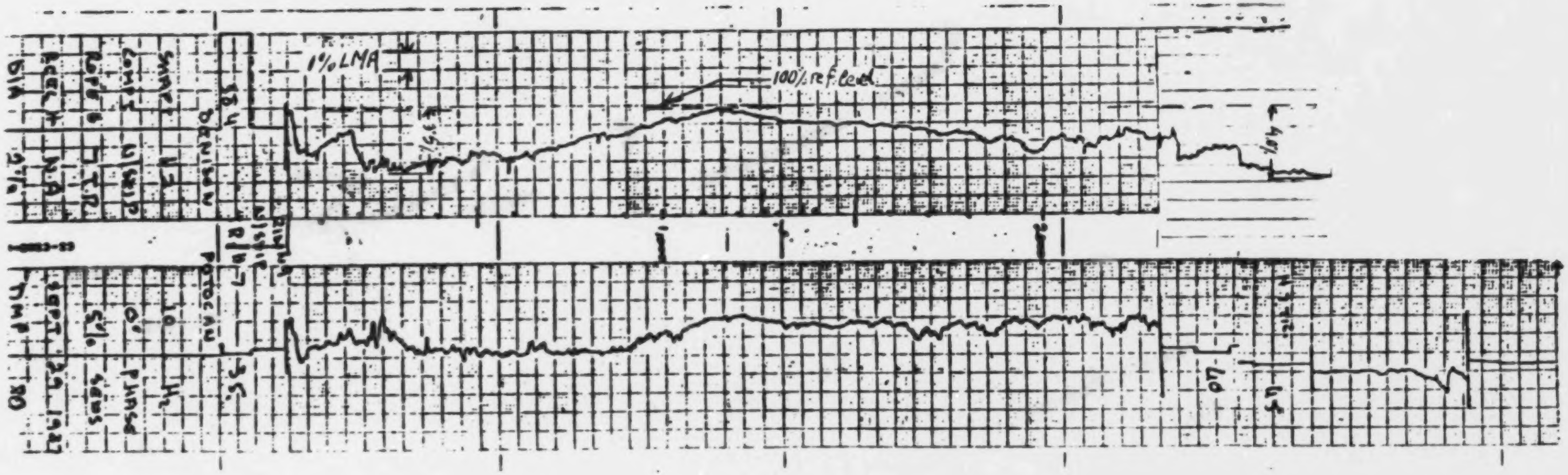


Fig. 1e — 29.9.87 Rotesco AC in situ test of tail-rope #7 (Fig. 1c), as respliced and marked by authors

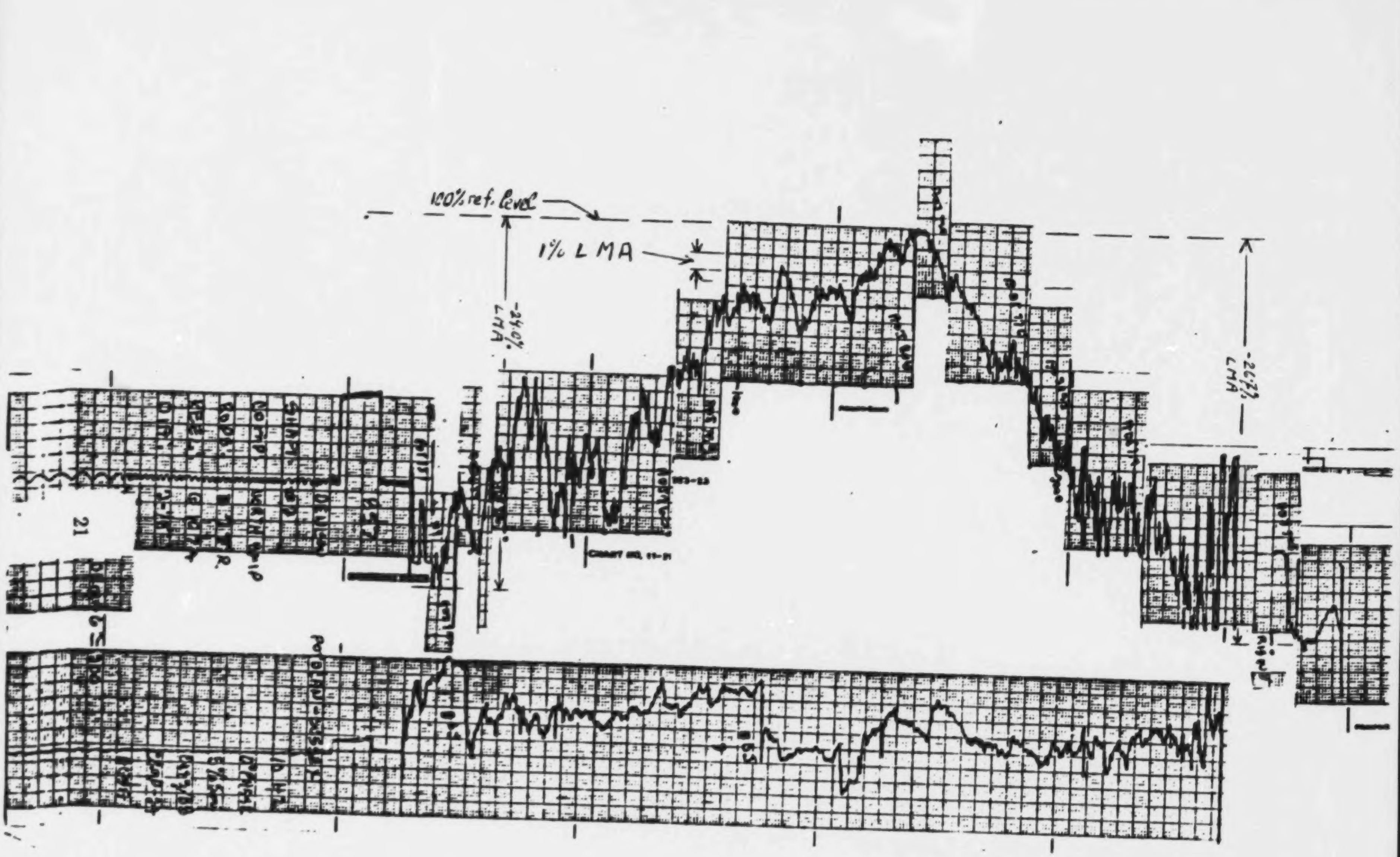


Fig. 1f — 3.10.88 Rotesco AC in situ test of tail-rope #7 (Fig. 1d), as respliced and marked by authors

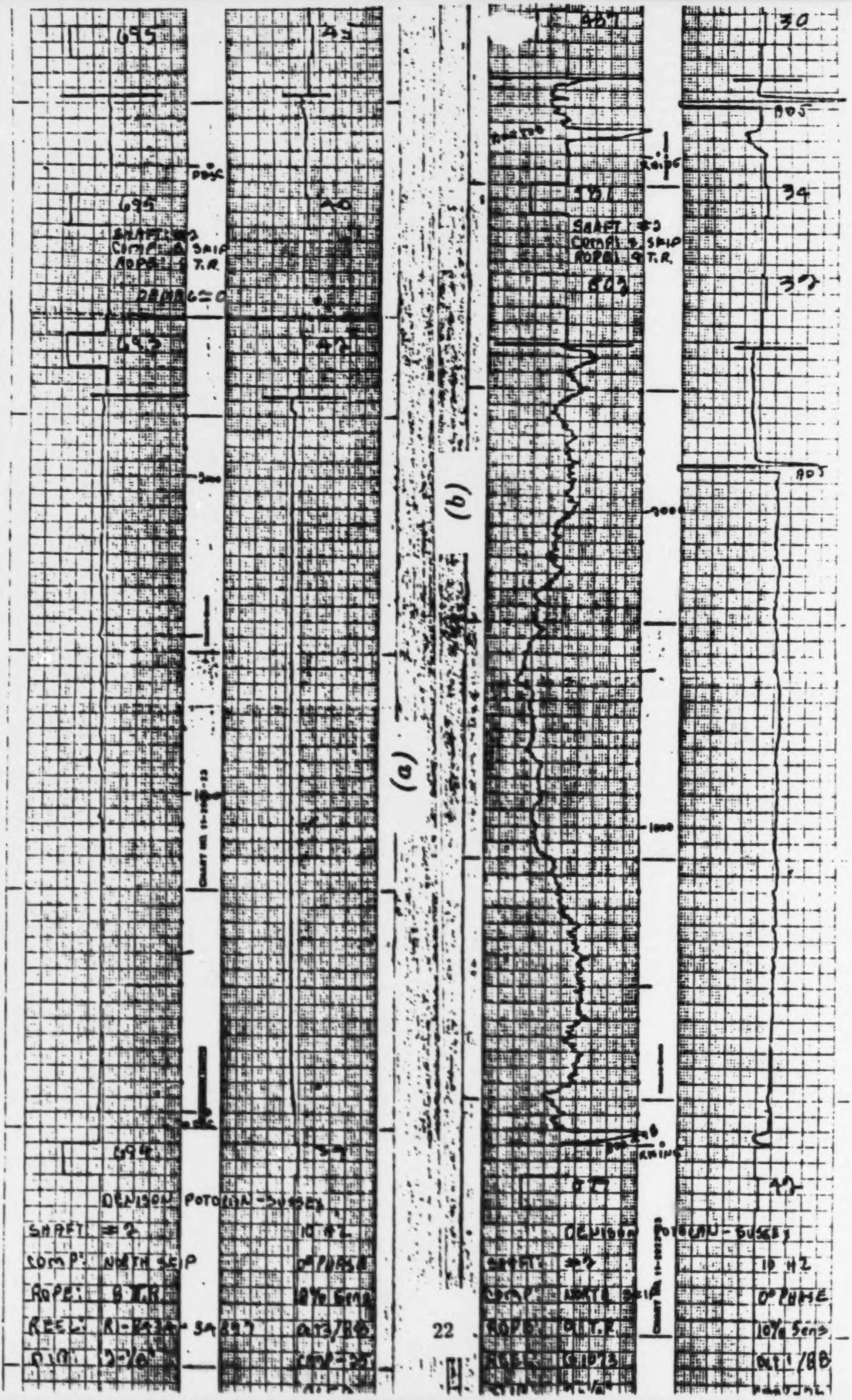


Fig. 2 — 3.10.88 Rotesco AC in situ test on: (a) tail-rope #8, and (b) tail-rope #0

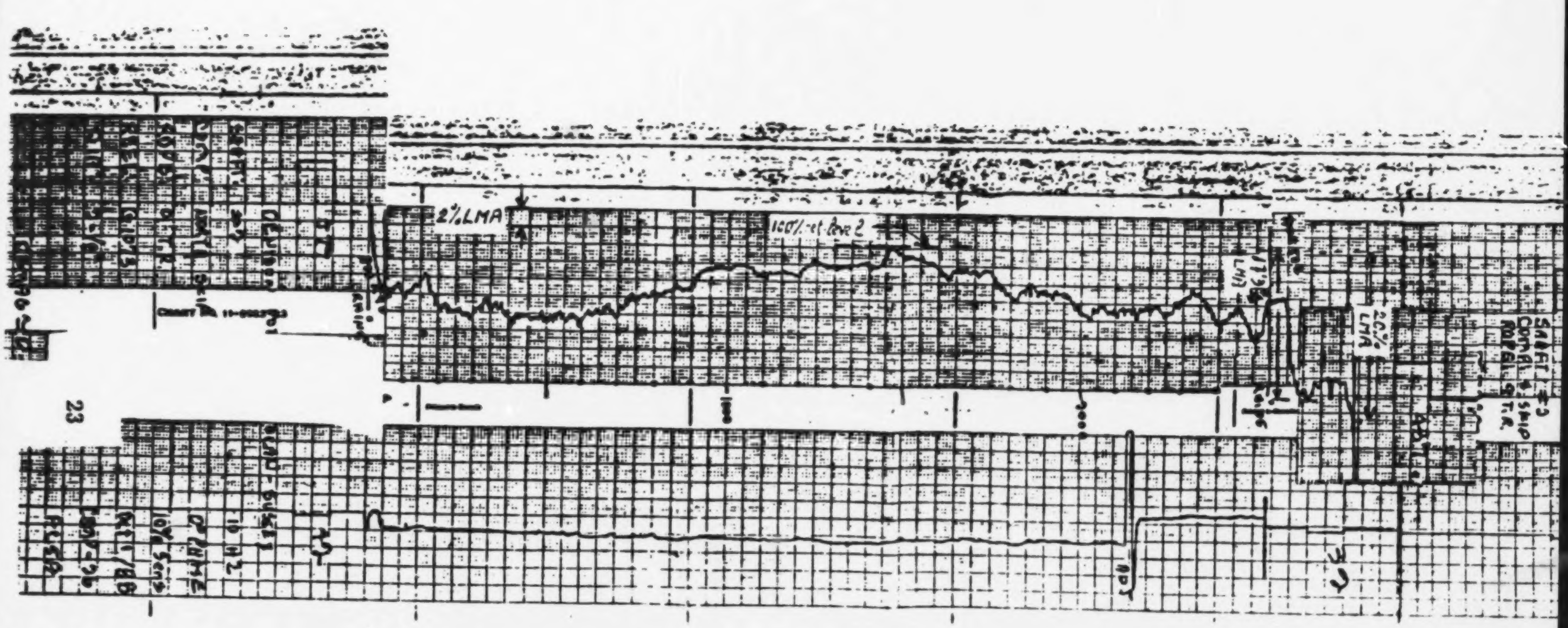


Fig. 2c — 3.10.88 Rotesco AC in situ test on tail-rope #9 (Fig. 2b), as marked by authors

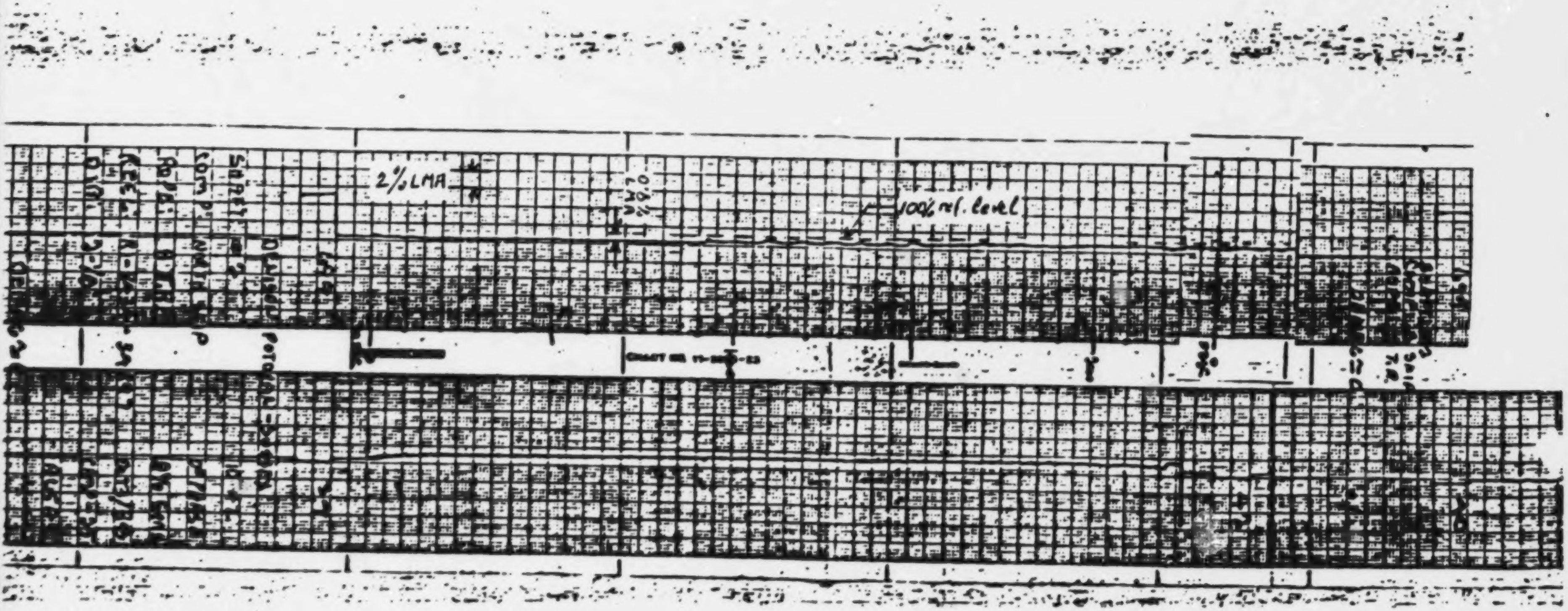


Fig. 2d — 3.10.88 Rotesco AC in situ test on tail-rope #8 (Fig. 2a), as marked by authors

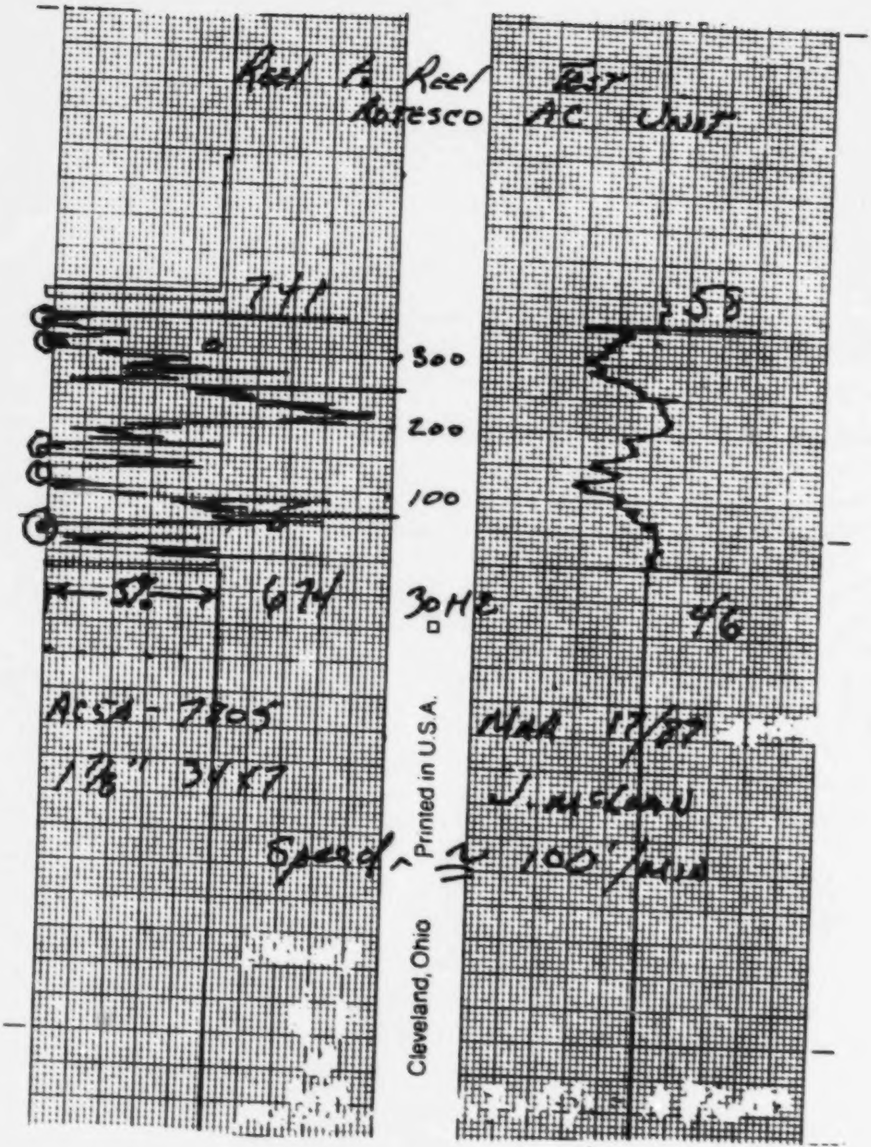
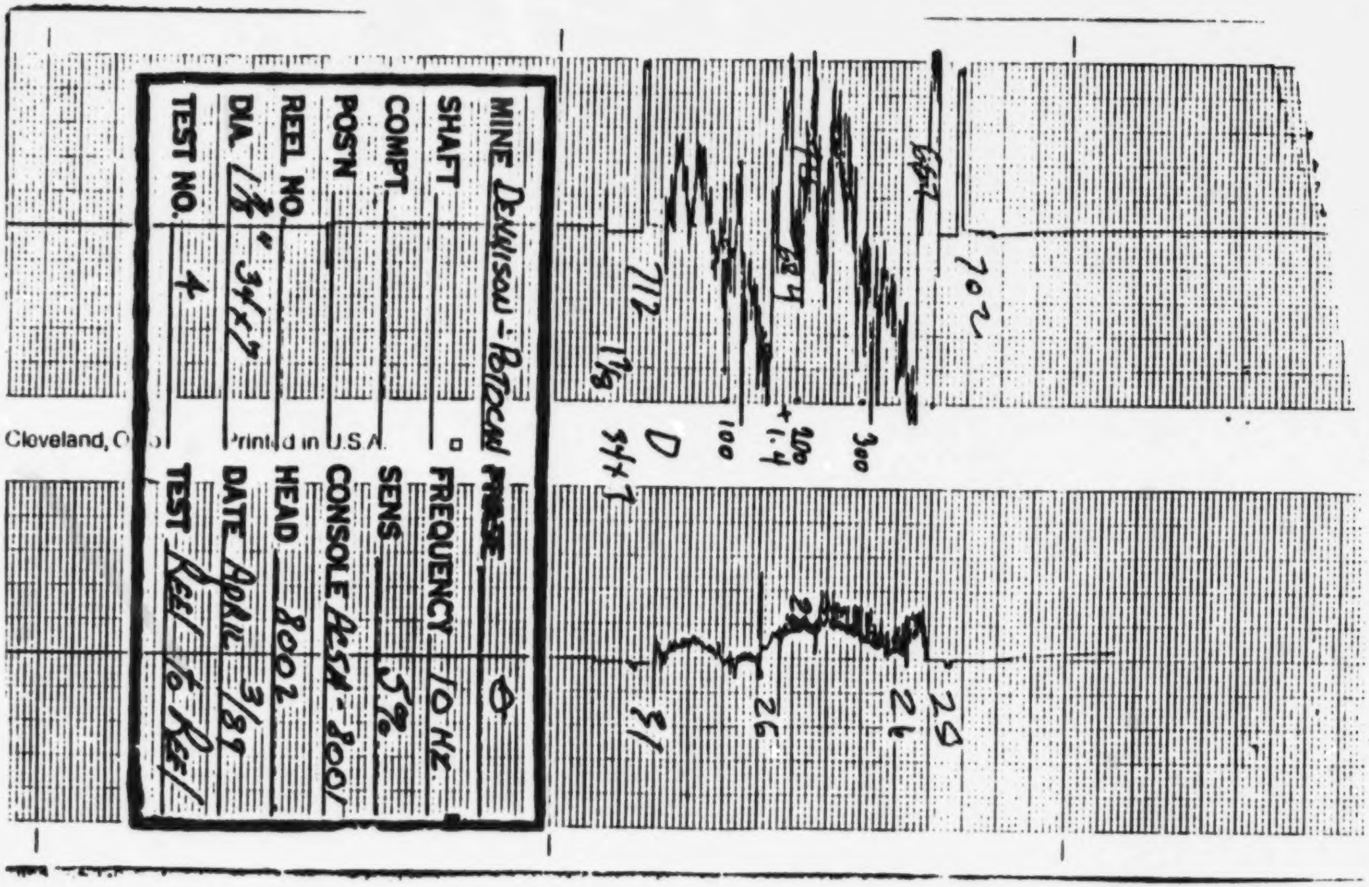


**Fig. 3a** — 17.3.89 Rotesco AC shop-floor test on our rope #0



| | |
|---|---|
| MINE Dennison - Potocan | PHASE 0 |
| SHAFT | FREQUENCY 10 Hz |
| COMPT | SENS 5% |
| POS'N | CONSOLE ACSA - 8001 |
| REEL NO. | HEAD 8002 |
| DIA. 1 7/8" 34x7 | DATE April 3/89 |
| TEST NO. 4 | TEST Reel to Reel |

Fig. 3b — 3.4.89 Rotesco AC shop-floor test on our rope #9

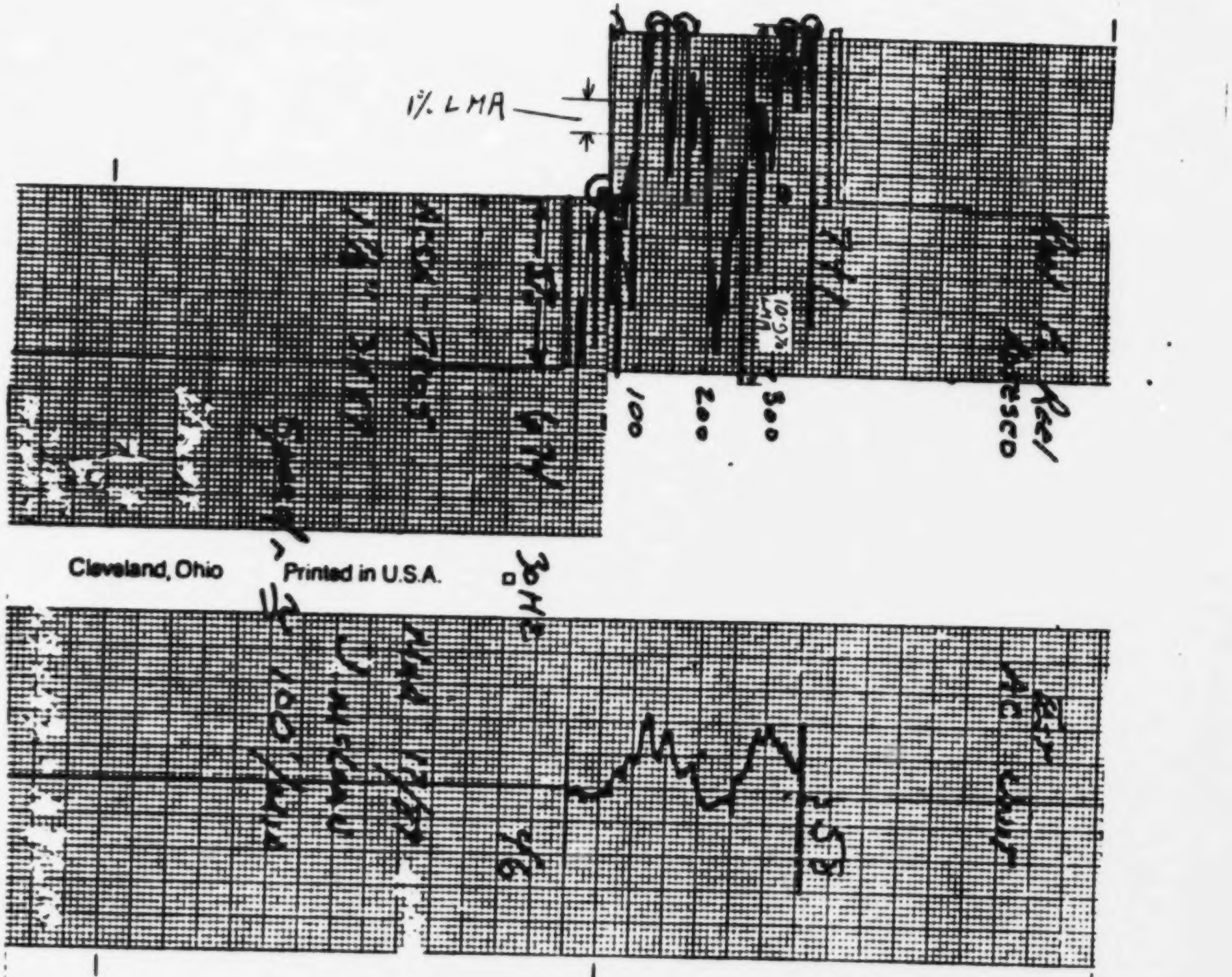
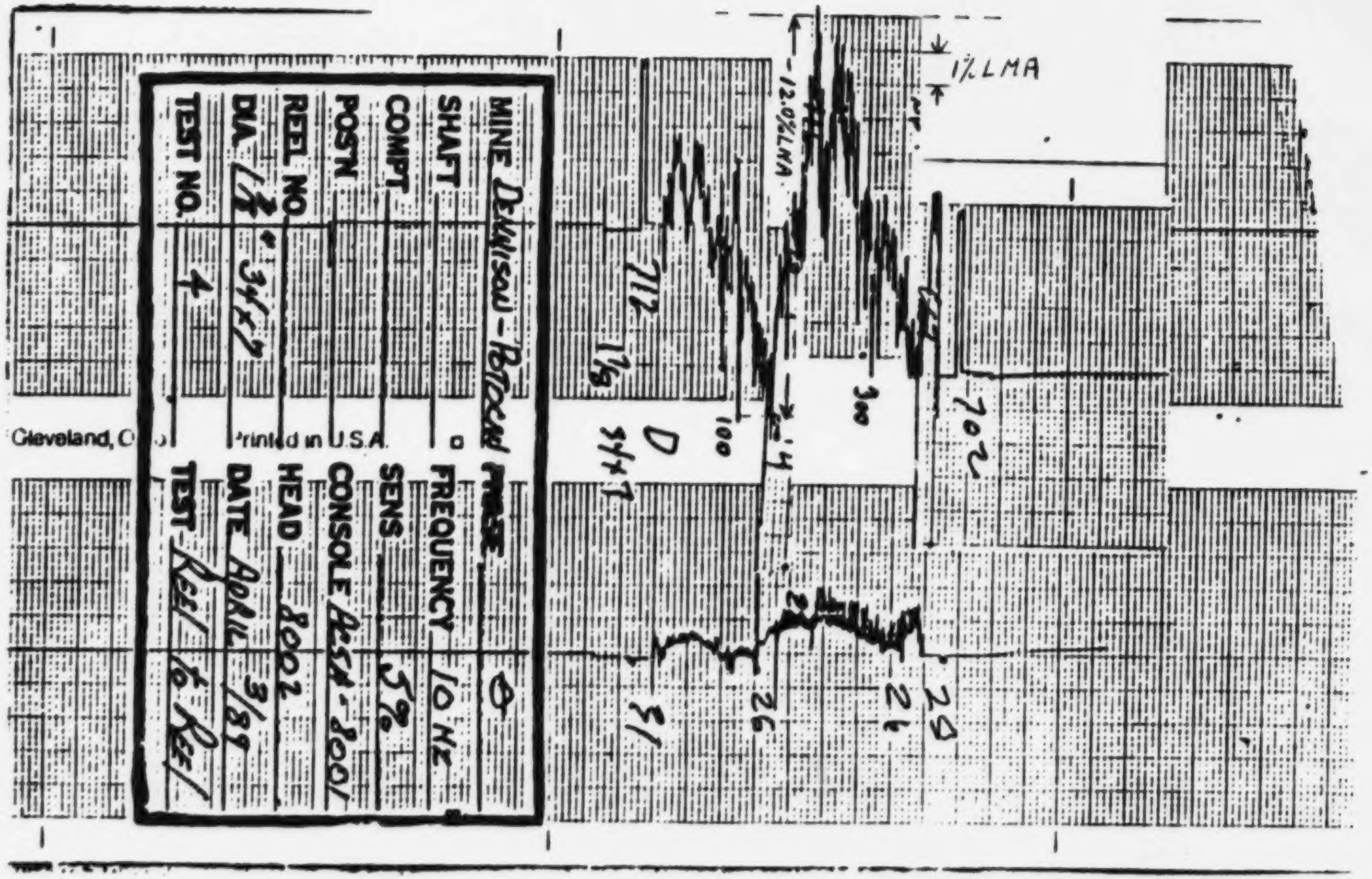


Fig. 3c — 17.3.89 Rotesco AC shop-floor test on our rope #0 (Fig. 3a), as respliced and marked by authors



MINE DENNISON - POTOCAN

SHAFT

COMPT

POS'N

REEL NO.

DIA. 1⅞" 34×7

TEST NO. 4

PHASE 0

FREQUENCY 10 HZ

SENS 5%

CONSOLE ACSA-8001

HEAD 8002

DATE APRIL 3/89

TEST Reel to Reel

Fig. 3d — 3.4.89 Rotesco AC shop-floor test on our rope #0 (Fig. 3b), as respliced and marked by authors

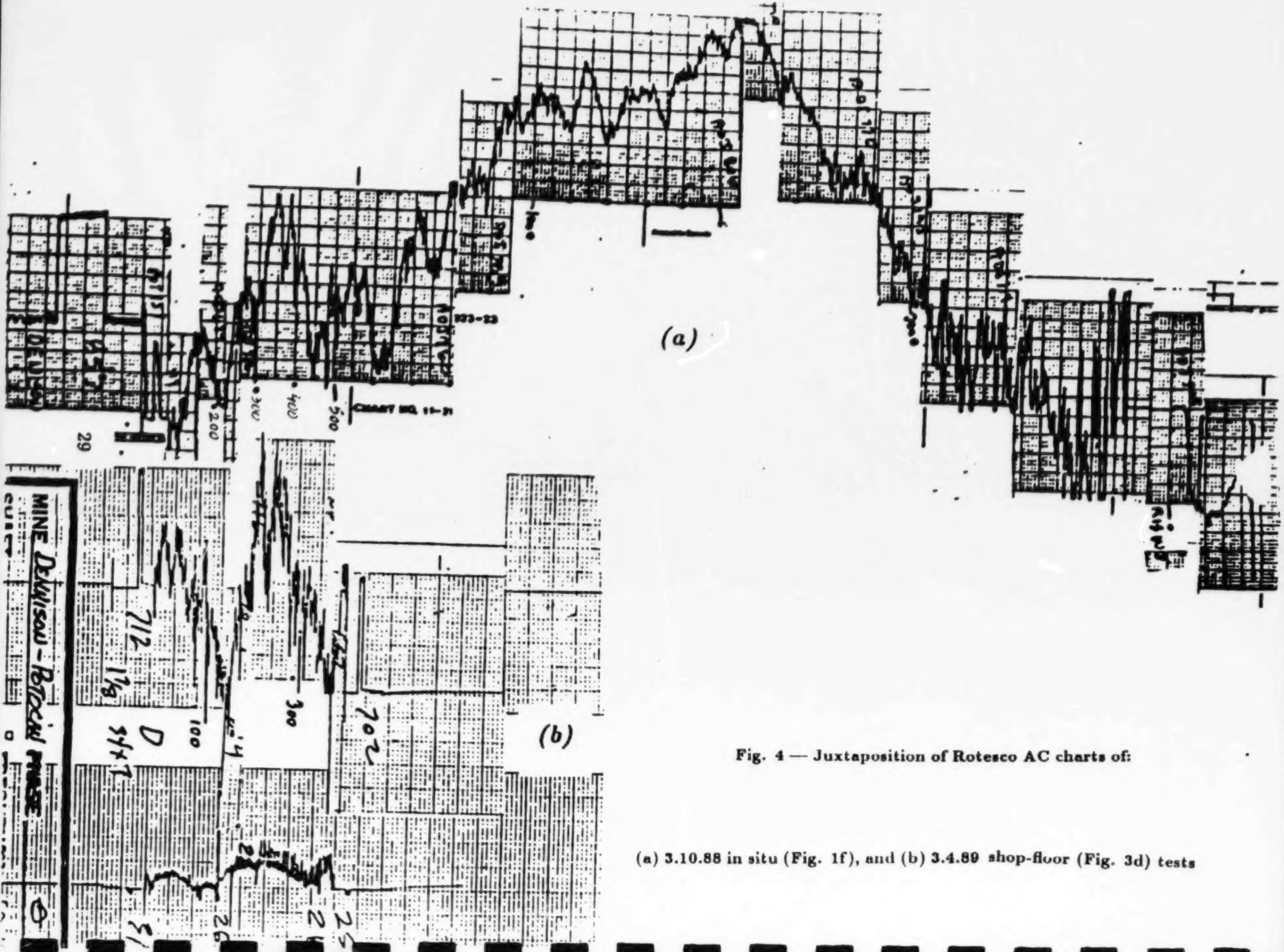


Fig. 4 — Juxtaposition of Rotesco AC charts of:

(a) 3.10.88 in situ (Fig. 1f), and (b) 3.4.89 shop-floor (Fig. 3d) tests

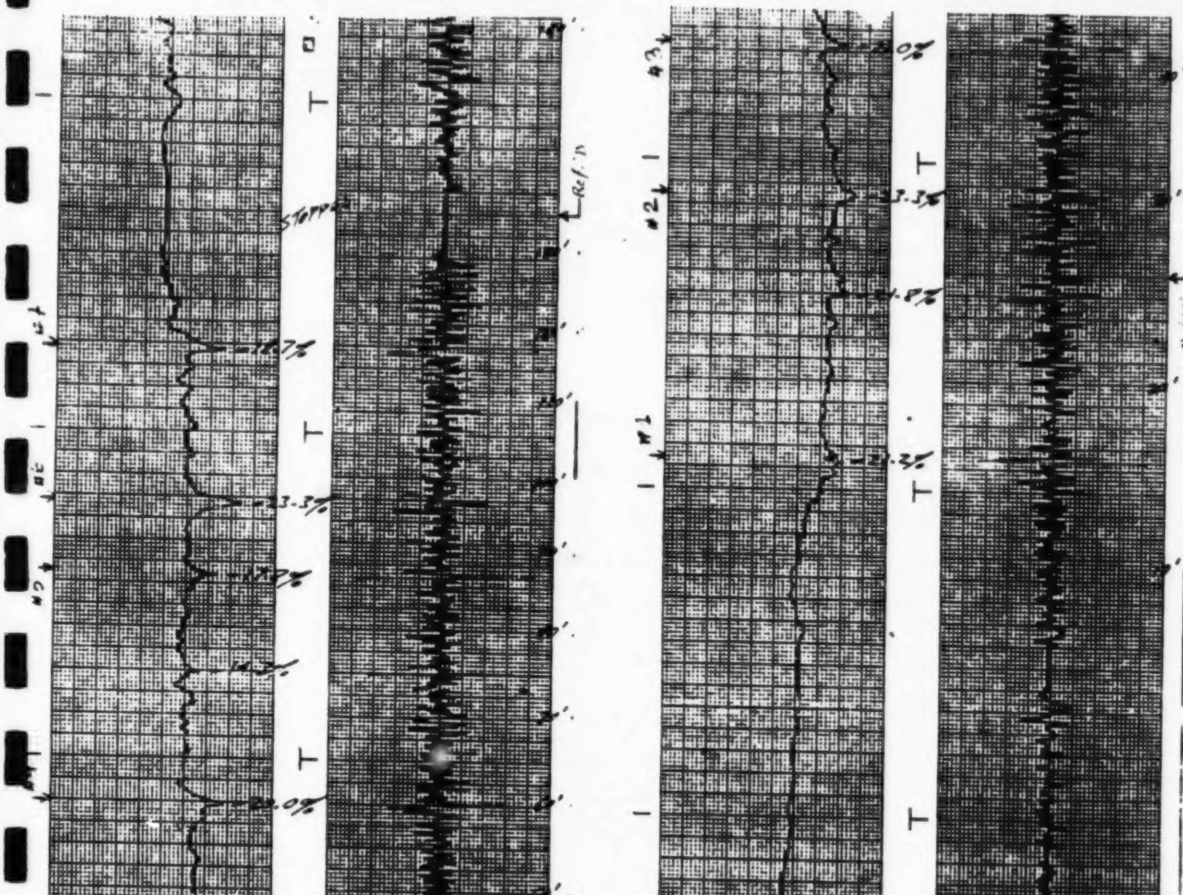


Fig. 5a — 17.3.80 LMA-250 shop-floor test on our rope #0

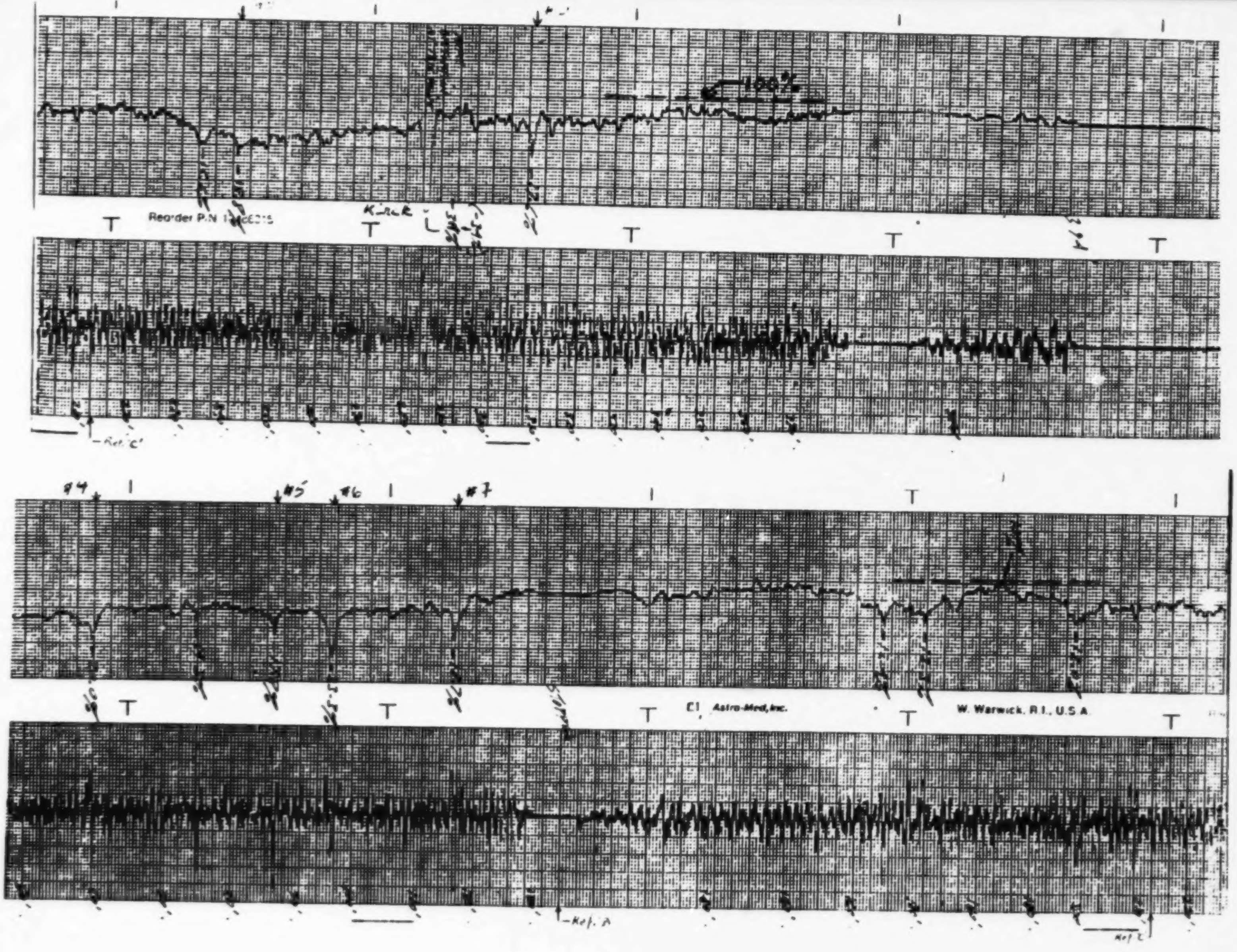


Fig. 5a (continued) -- 17.3.89 LMA-250 shop-floor test on our rope #0

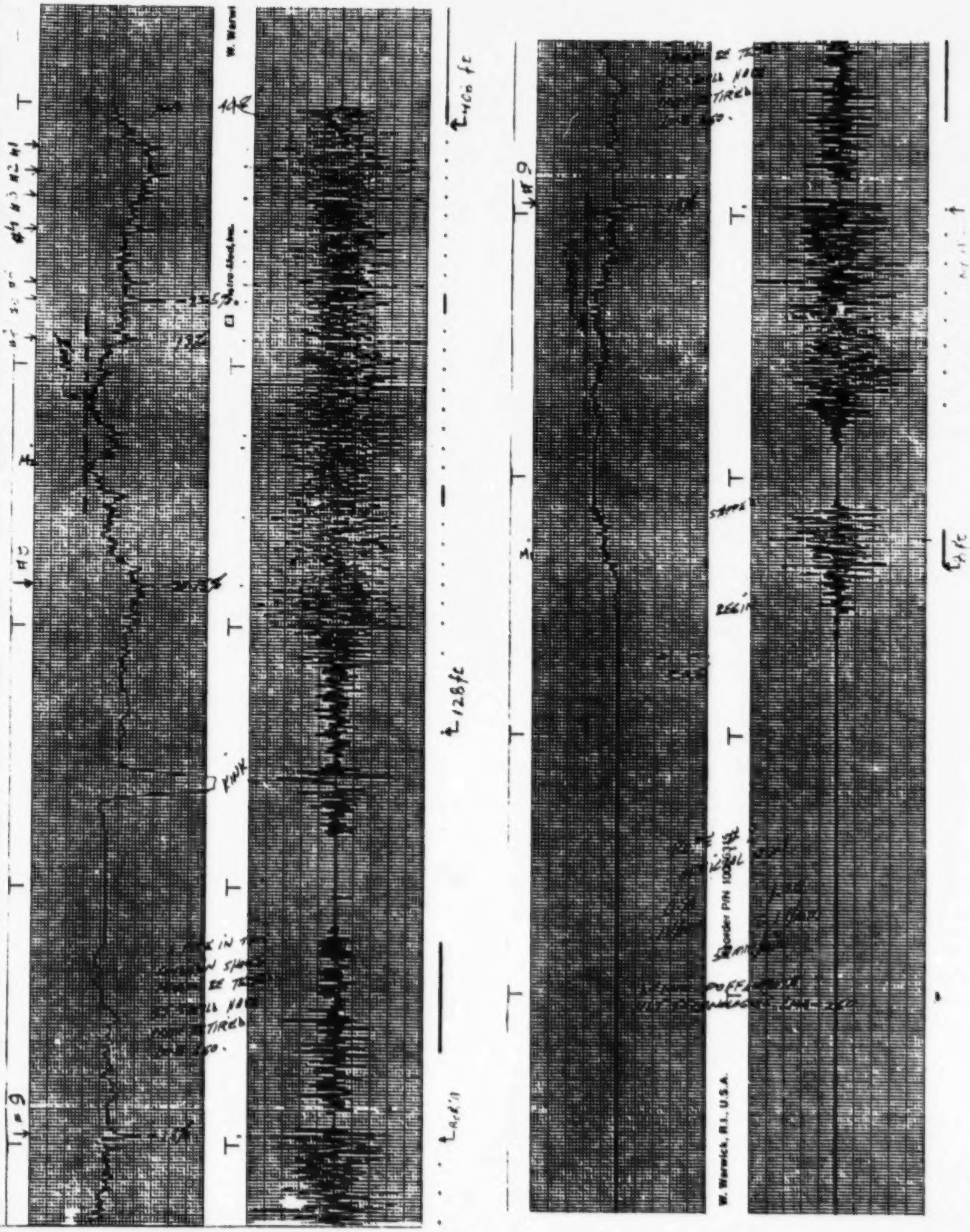


Fig. 5b — 4.4.89 LMA-250 shop-floor test on our rope #0

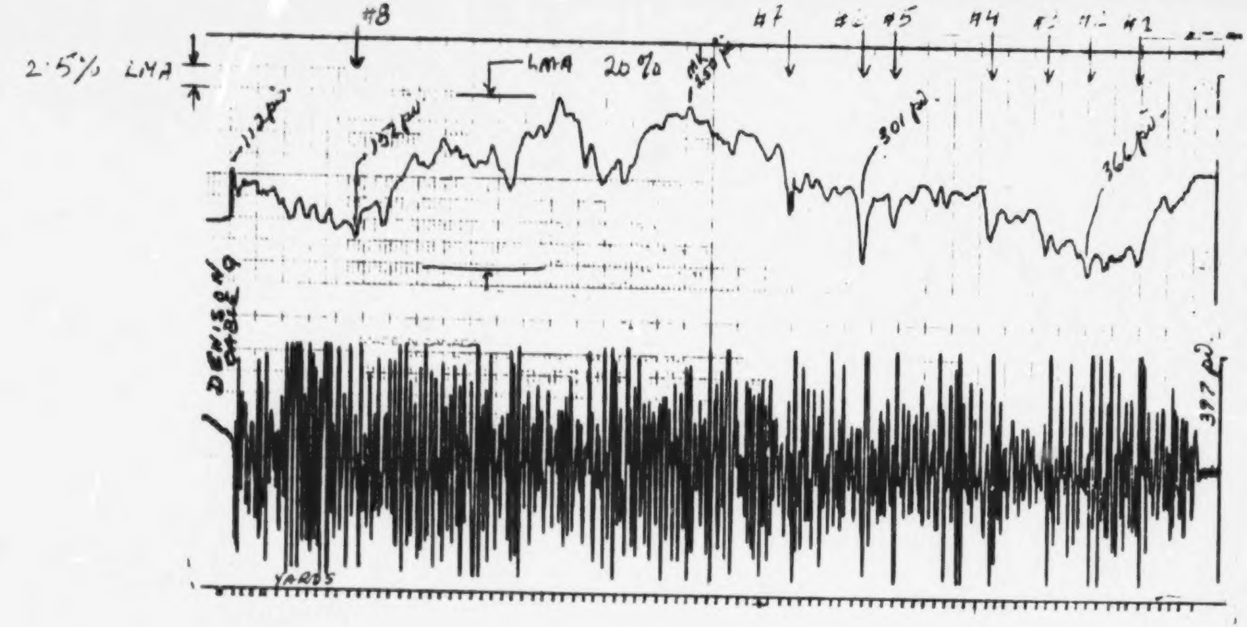


**Fig. 6a** — 4.4.89 Magnograph shop-floor test on our rope #9: partial chart, as submitted by operator

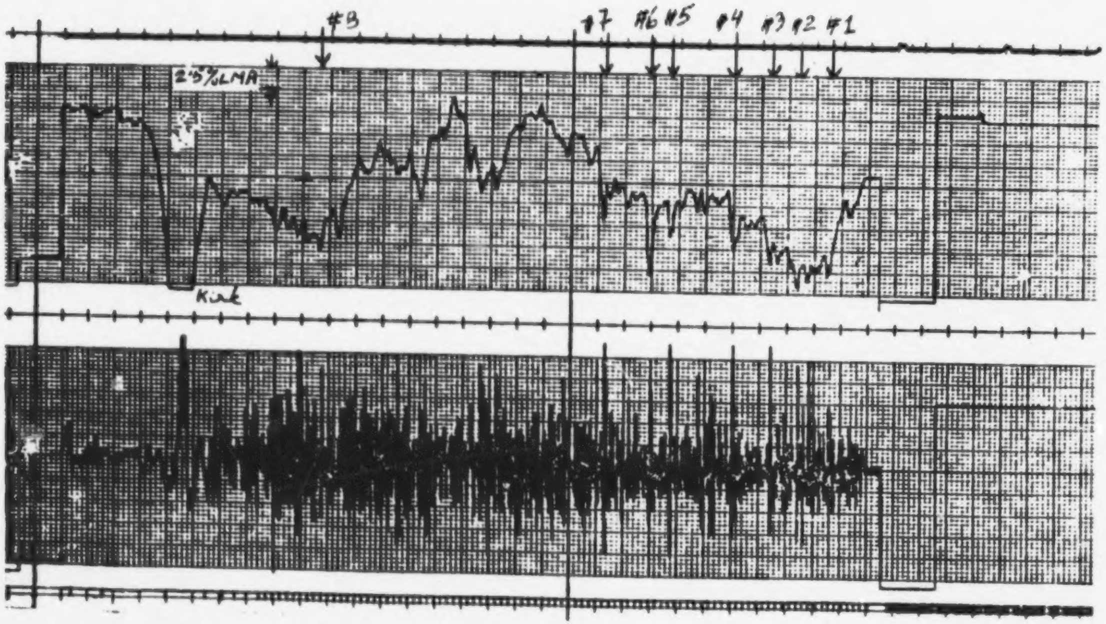
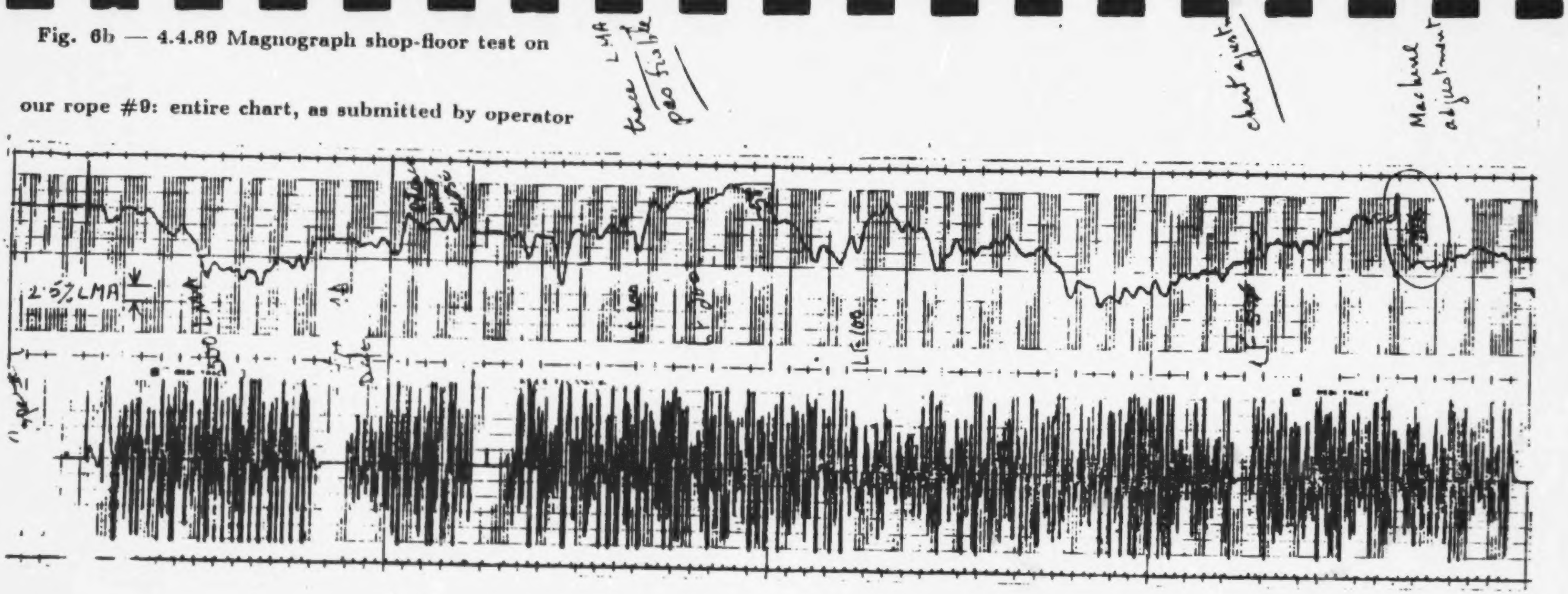


**Fig. 6d** — 4.4.89 Magnograph shop-floor test on our rope #9: chart as obtained by authors from operator's test-tape; 2.5% LMA per major chart-division

Fig. 6b — 4.4.89 Magnograph shop-floor test on our rope #9: entire chart, as submitted by operator



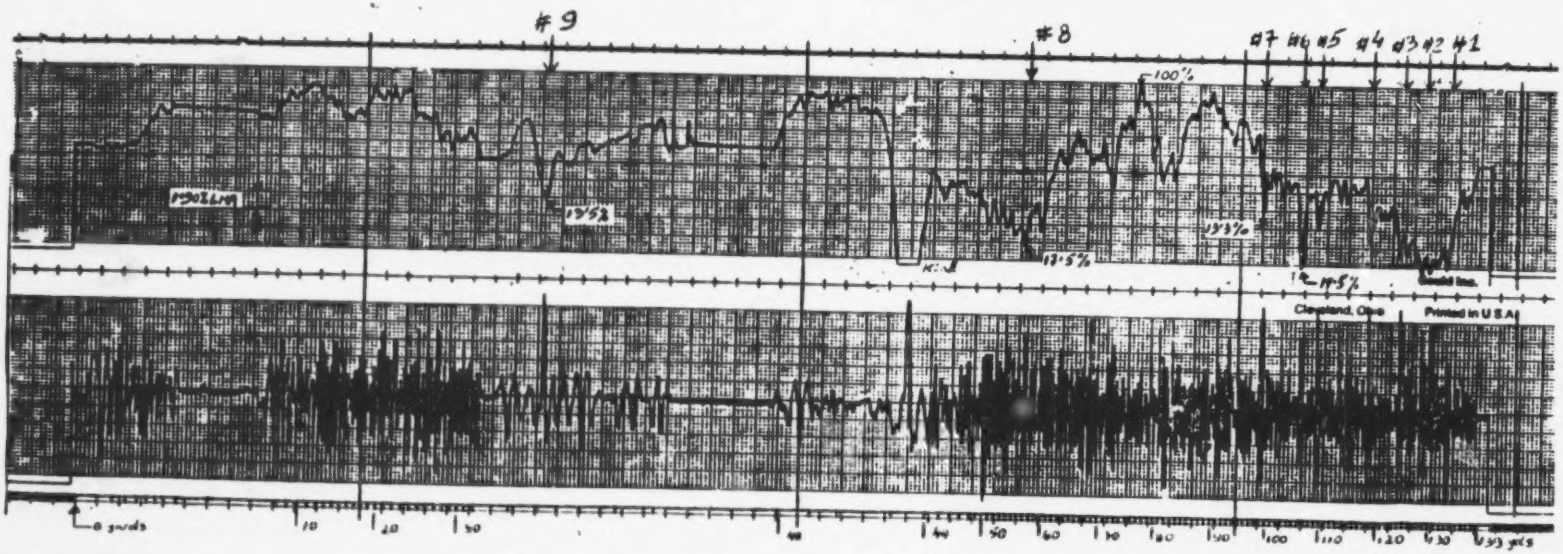


Fig. 6c — 4.4.89 Magnograph shop-floor test on our rope #9: chart as obtained by authors from operator's test-tape; 1.9% LMA per major chart-division

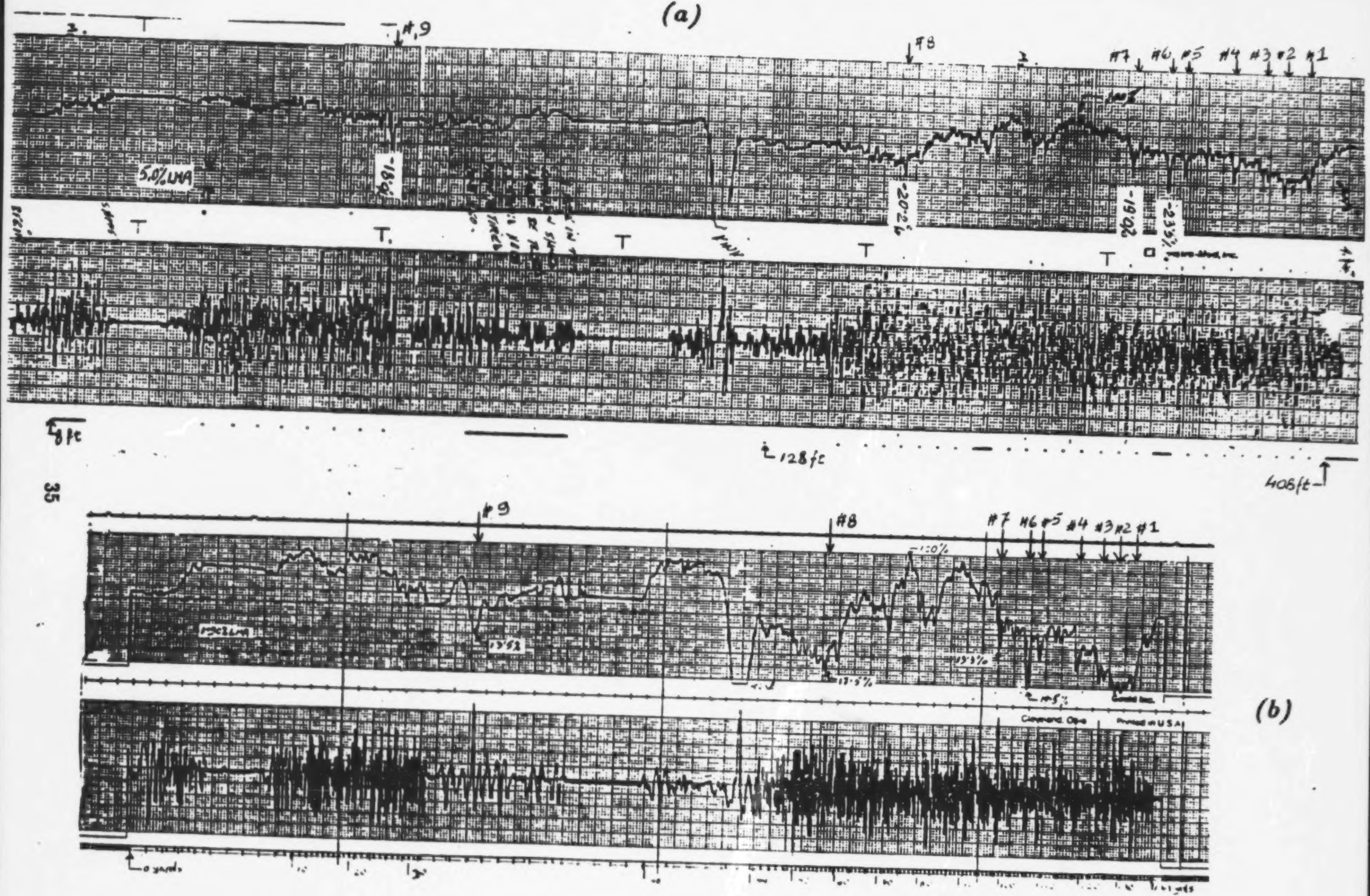


Fig. 6e — juxtaposition of 4.4.89 shop-floor test charts on our rope #9: (a) LMA-250 (Fig. 5b) chart, and (b) Magnograph (Fig. 6c) chart

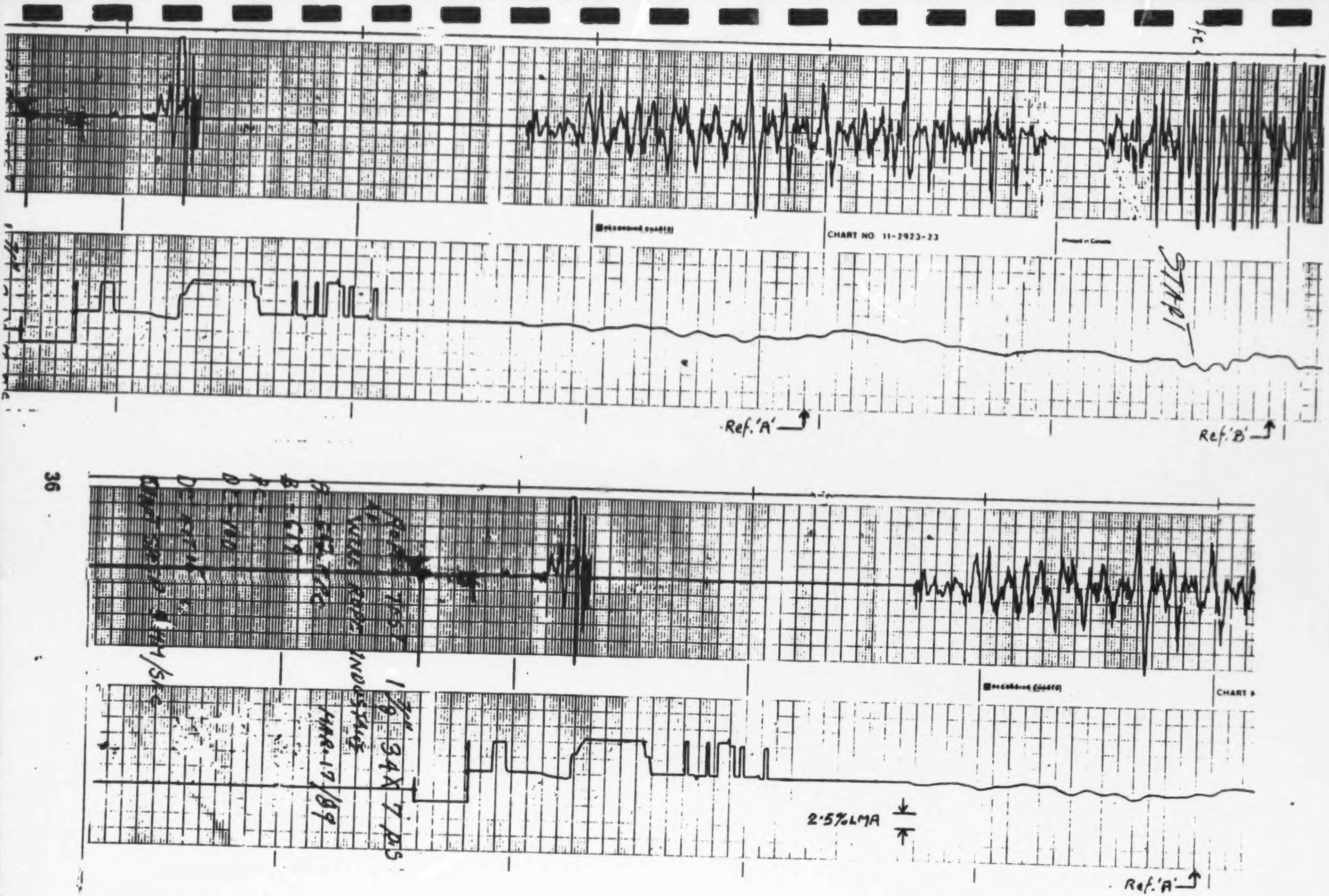


Fig. 7a — 17.3.89 Rotescograph shop-floor test on our rope #9

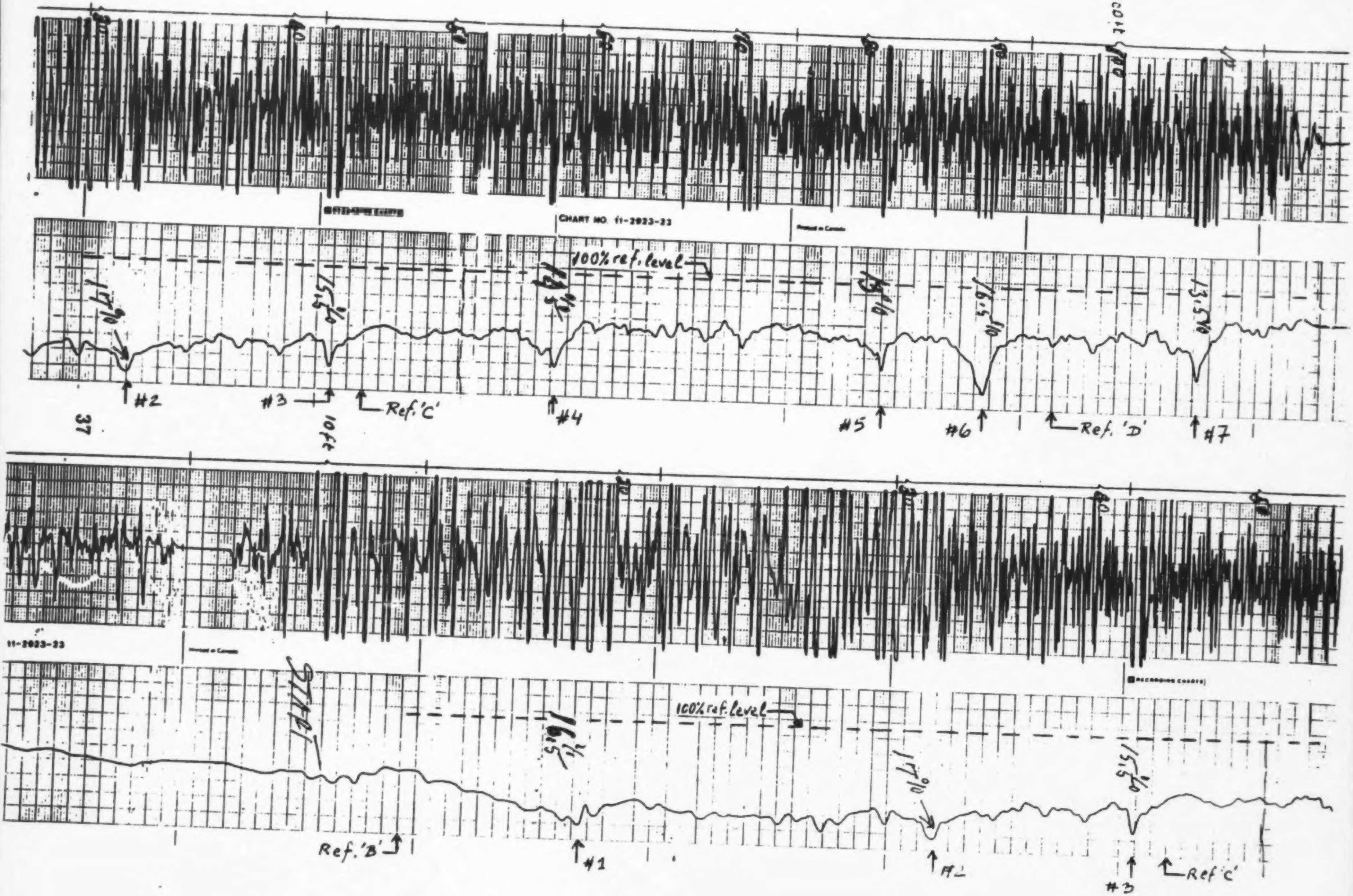


Fig. 7a (continued) — 17.3.89 Rotescograph shop-floor test on our rope #9

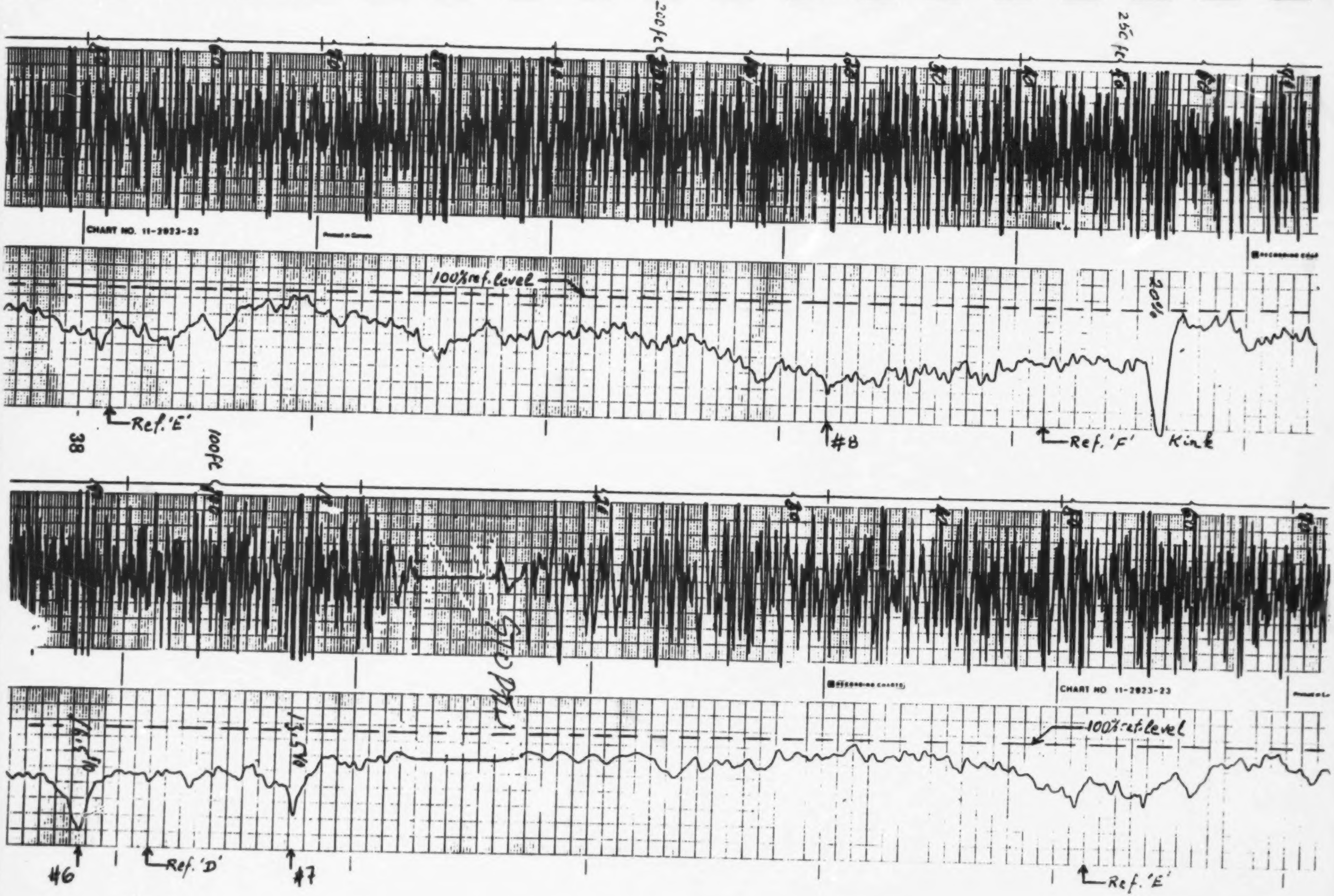


Fig. 7a (continued) — 17.3.89 Rotescograph shop-floor test on our rope #9

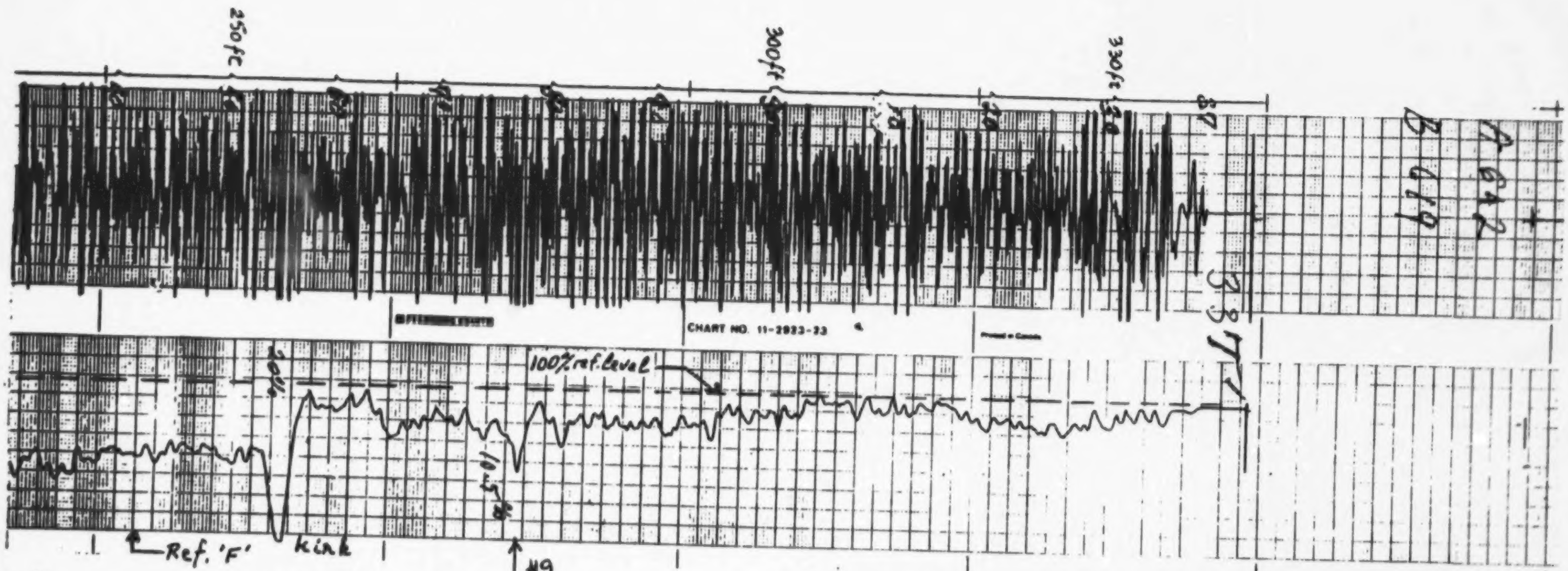


Fig. 7a (continued) — 17.3.89 Rotescograph shop-floor test on our rope #9

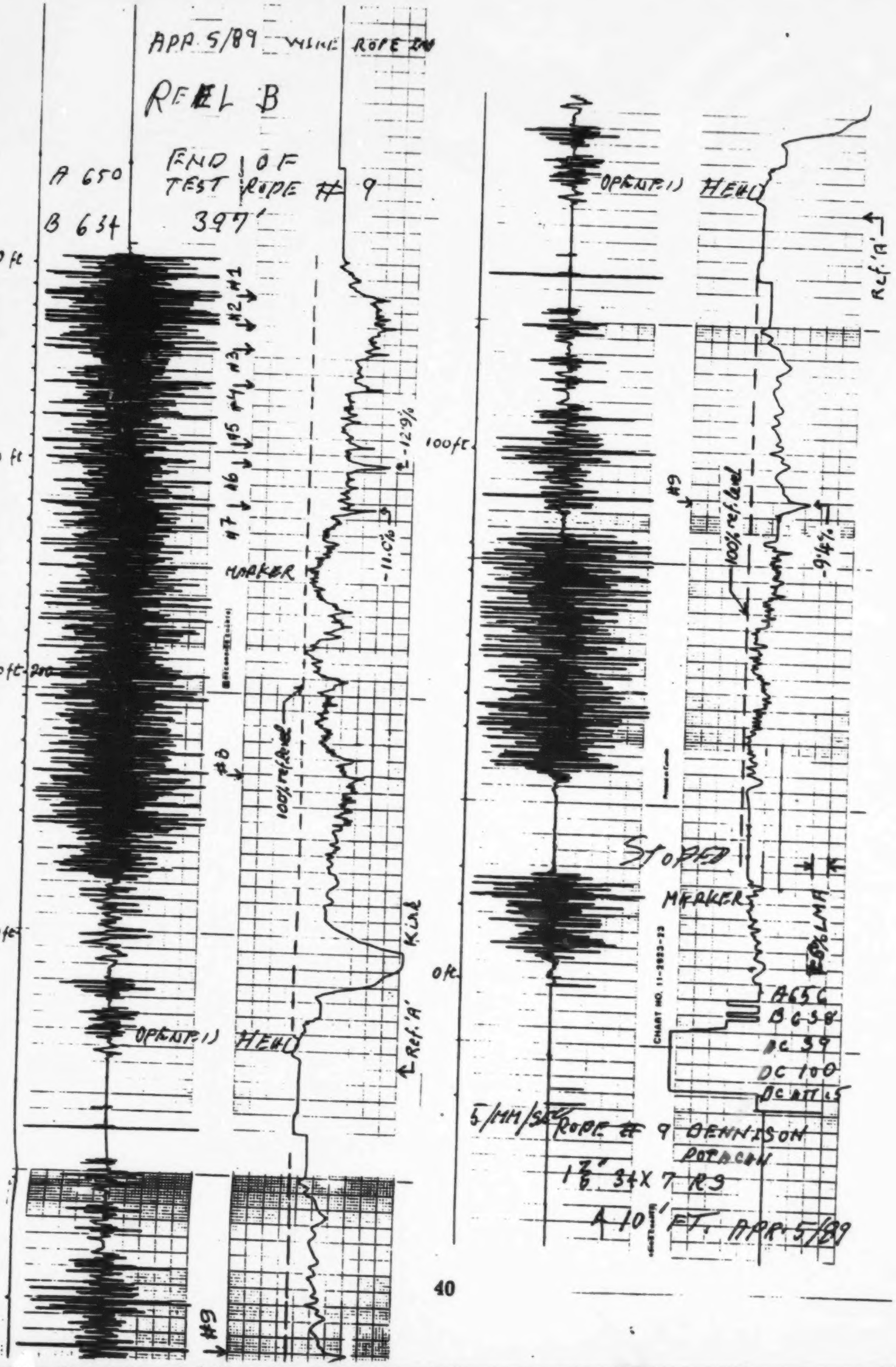


Fig. 7b — 5.4.89 Rotescograph shop-floor test on our rope #9

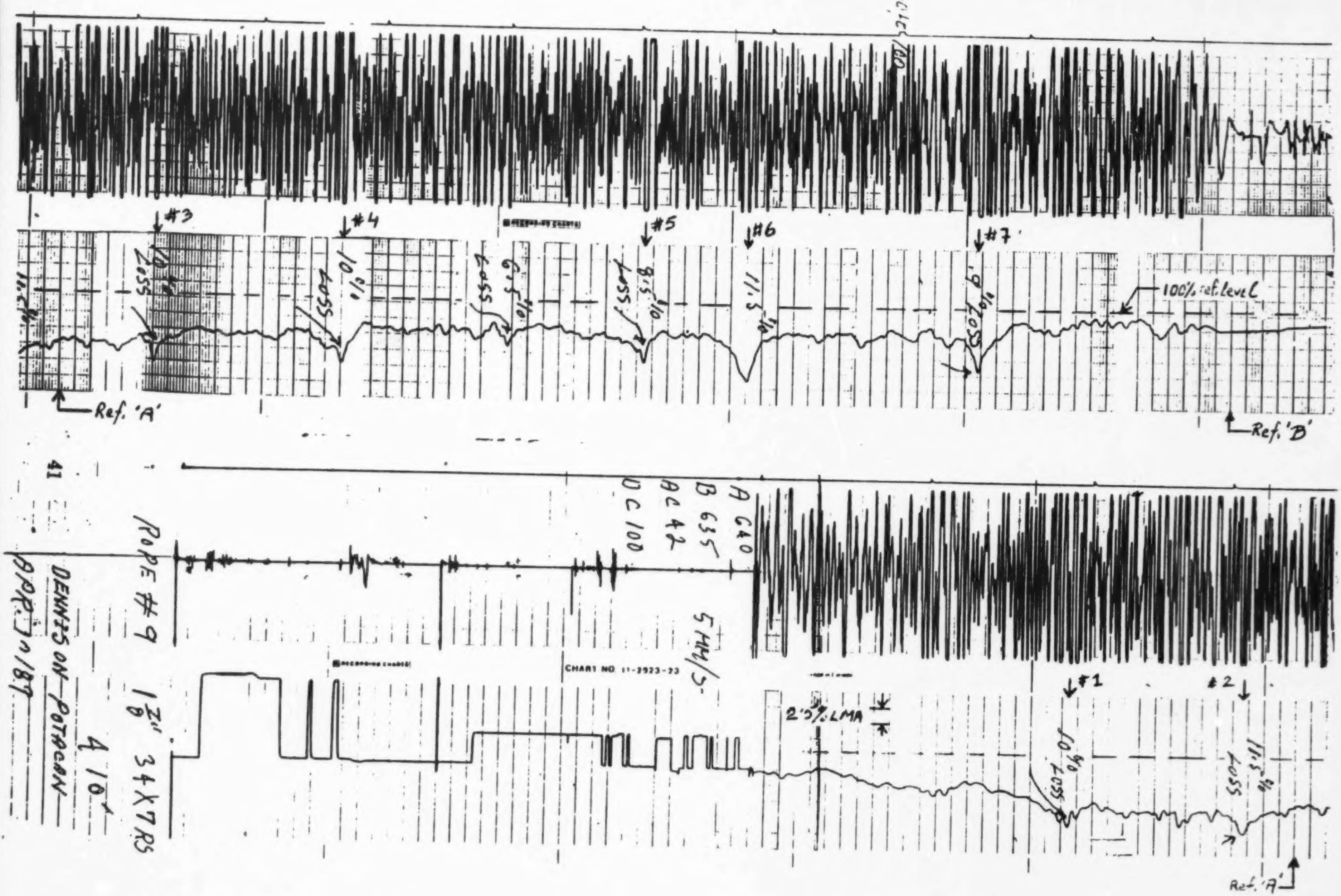


Fig. 7c — 10.4.89 Rotescograph shop-floor test on our rope #9

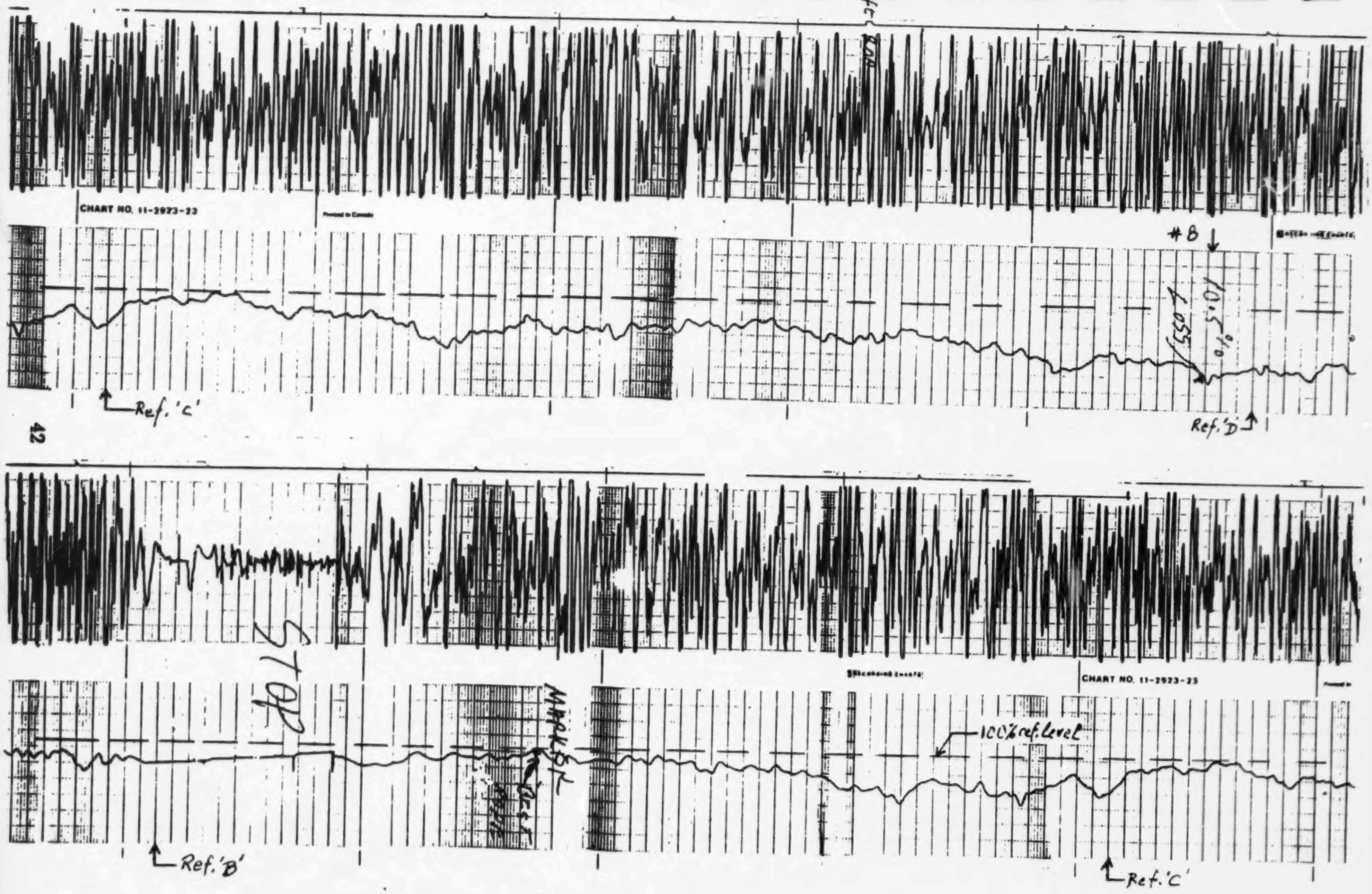


Fig. 7c (continued) — 10.4.89 Rotescograph shop-floor test on our rope #9

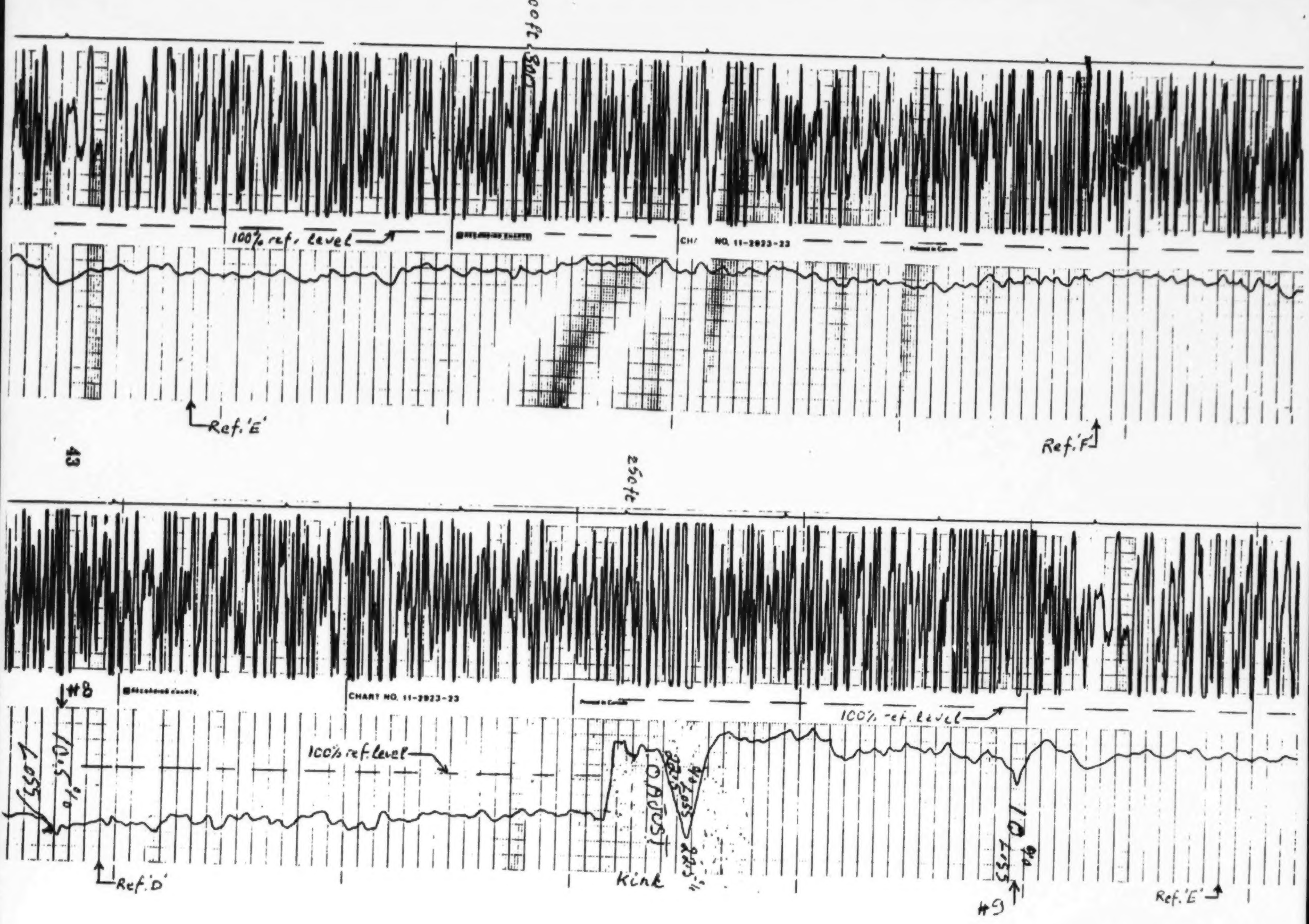


Fig. 7c (continued) — 10.4.89 Rotescograph shop-floor test on our rope #9

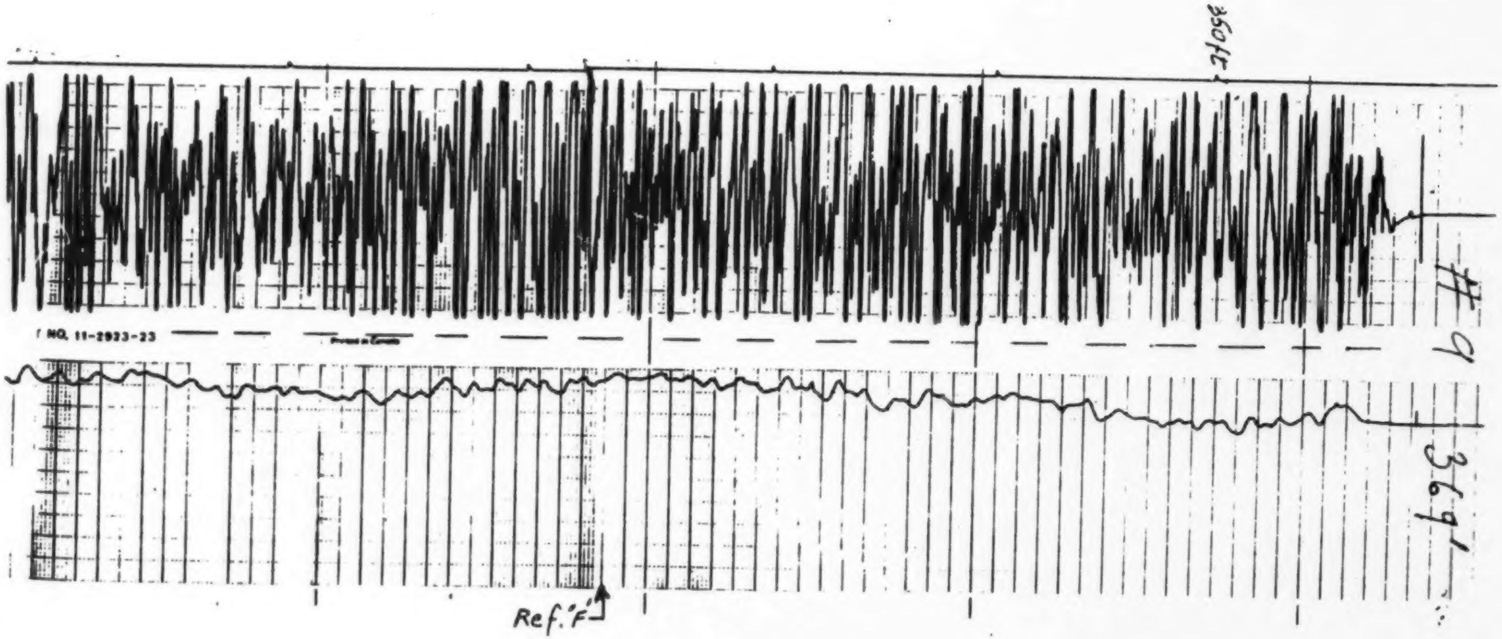


Fig. 7c (continued) — 10.4.89 Rotescograph shop-floor test on our rope #9

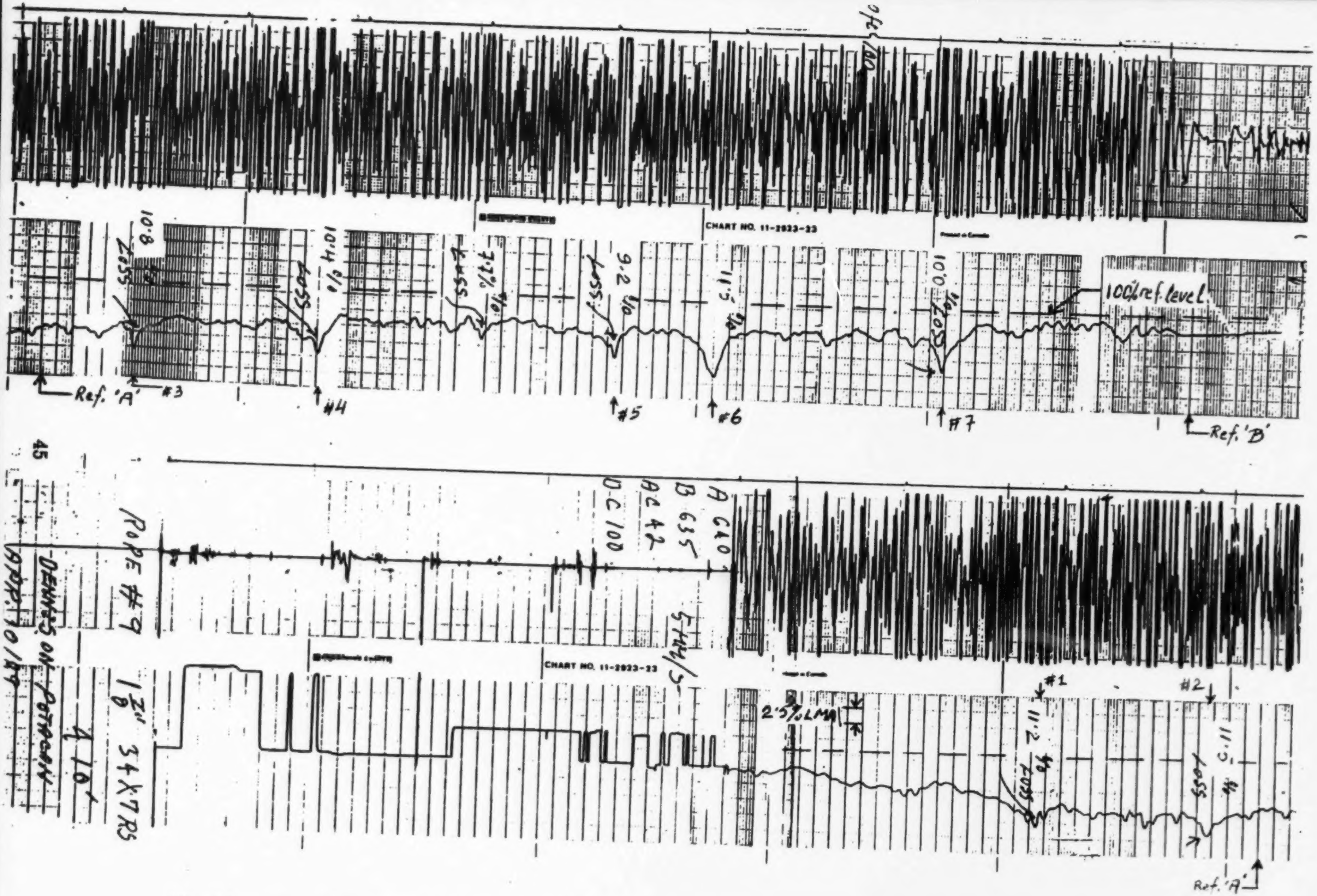


Fig. 7d — 10.4.89 Rotescograph shop-floor test on our rope #9 (Fig. 7c): as respliced and marked by authors

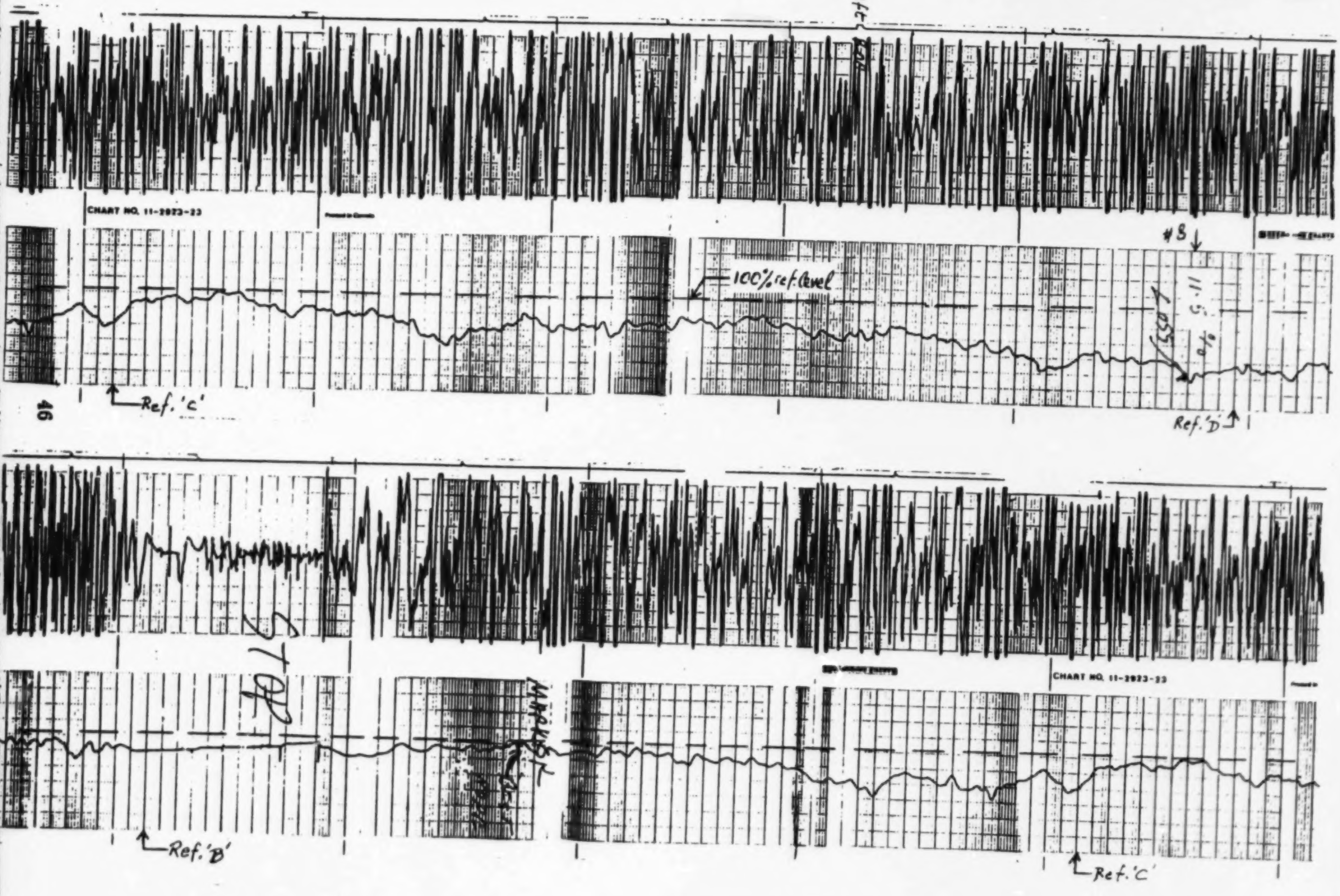


Fig. 7d (continued) — 10.4.89 Rotescograph shop-floor test on our rope #8 (Fig. 7c): as respliced and marked **by authors**

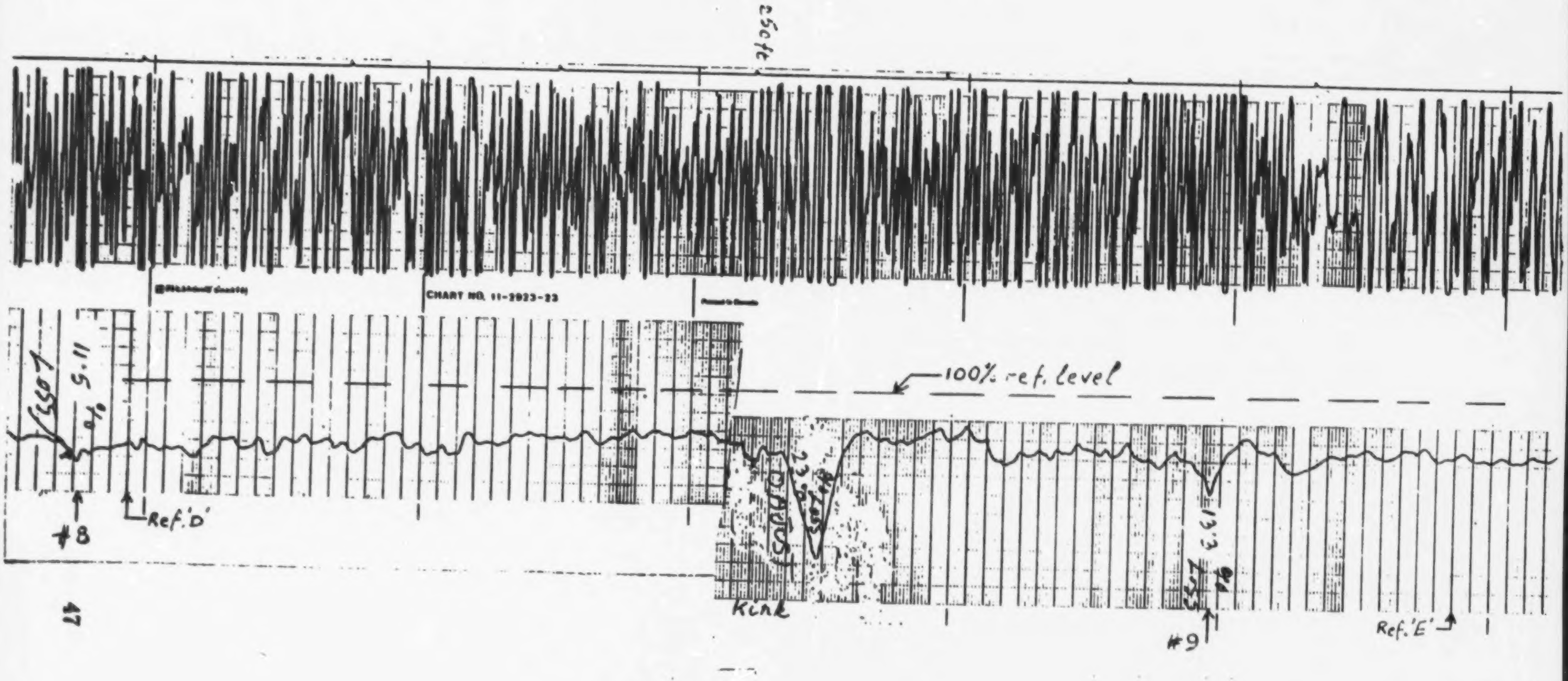


Fig. 7d (continued) — 10.4.89 Rotescograph shop-floor test on our rope #9 (Fig. 7c): as respliced and marked by authors

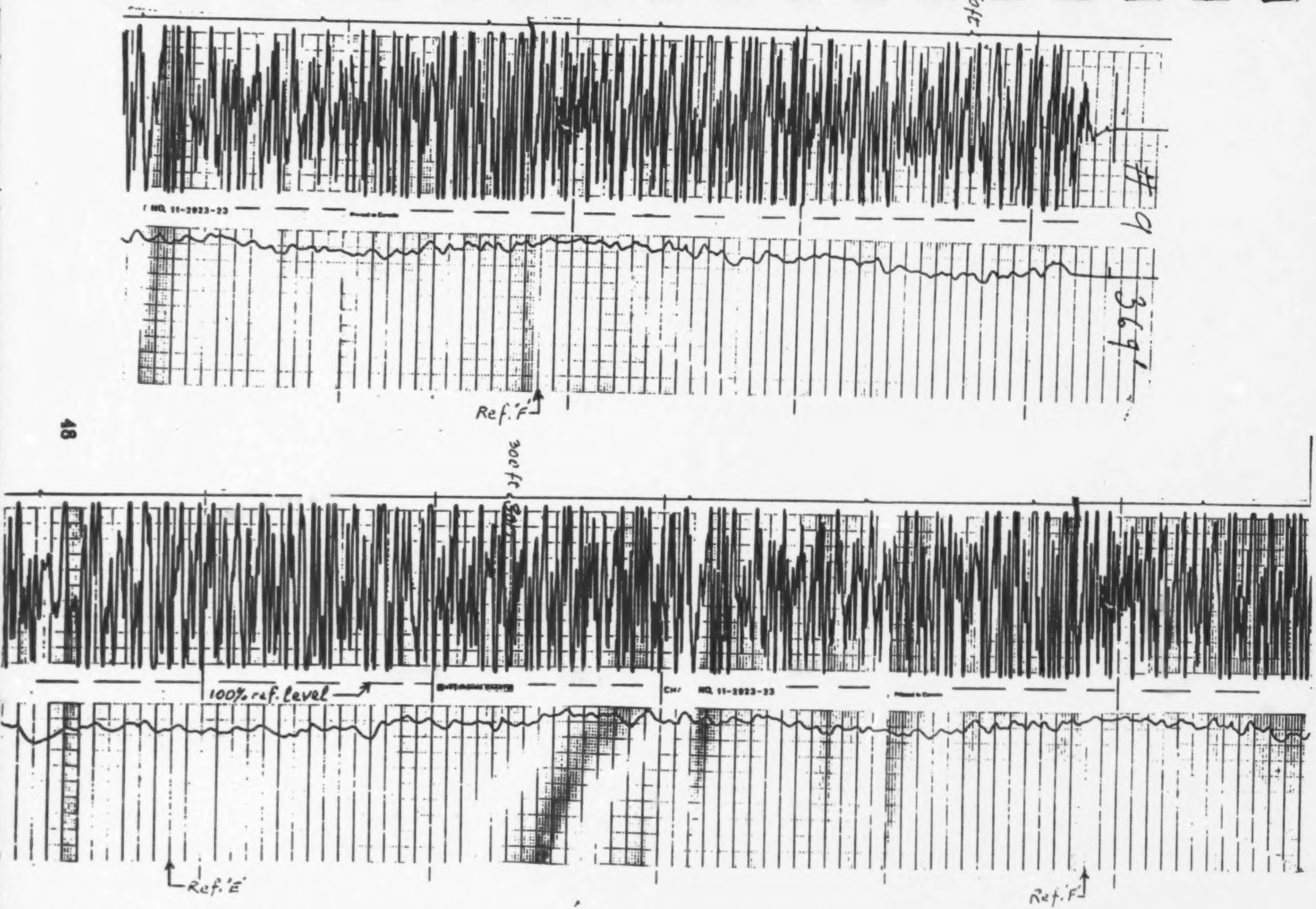


Fig. 7d (continued) — 10.4.89 Rotescograph shop-floor test on our rope #9 (Fig. 7c): as respliced and marked by authors